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PROCEEDINGS

of the

American Society

for

Horticultural Science

for Vol. 34

1936



Volume 34

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THIRTY-THIRD ANNUAL MEETING



ALEX LAURIE

PROCEEDINGS
OF THE
AMERICAN SOCIETY
FOR
HORTICULTURAL SCIENCE
FOR
1936

Thirty-third Annual Meeting
Atlantic City, New Jersey
December 29, 30, and 31, 1936

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OFFICERS AND COMMITTEES FOR 1937

<i>President</i>	A. J. HEINICKE
<i>Vice-President</i>	V. R. BOSWELL
<i>Sectional Chairmen</i>	L. C. CHADWICK, GEORGE F. POTTER, H. D. BROWN
<i>Local Arrangements</i>	C. L. BURKHOLDER, <i>Chairman</i>

EXECUTIVE COMMITTEE

	ALEX LAURIE, <i>Chairman</i>	
A. J. HEINICKE	J. R. COOPER (1937)	L. C. CHADWICK
V. R. BOSWELL	S. H. YARNELL (1938)	G. F. POTTER
H. B. TUKEY		H. D. BROWN

PROGRAM COMMITTEE

	L. H. MACDANIELS, <i>Chairman</i>	
R. B. WITHROW	ORA SMITH	H. B. TUKEY

NOMINATING COMMITTEE

	LAURENZ GREENE, <i>Chairman</i>	
A. J. OLNEY	KENNETH POST	T. M. CURRENCE
G. H. POESCH		A. M. BINKLEY

SECTIONAL GROUPS AND MEMBERSHIP

	S. L. EMSWELLER, <i>Chairman</i>	
E. L. OVERHOLSER	H. E. WHITE	H. P. TRAUB
W. D. KIMBROUGH		A. L. WILSON

REPRESENTATIVES ON A. A. A. S. COUNCIL

C. H. CONNORS	J. K. SHAW
---------------	------------

REPRESENTATIVES ON BOTANICAL AND BIOLOGICAL ABSTRACTS

F. C. BRADFORD	JOHN BUSHNELL
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REPRESENTATIVE ON NATIONAL RESEARCH COUNCIL

E. C. AUCHTER

EDITORIAL COMMITTEE

F. C. BRADFORD, *Chairman* (1941)

ROY MAGRUDER (1937)	E. F. PALMER (1939)
R. C. ALLEN (1938)	W. A. RUTH (1940)

CONSTITUTION*

ARTICLE I

The name of this Association shall be the American Society for Horticultural Science.

ARTICLE II

The object of the Society shall be to promote the Science of Horticulture.

ARTICLE III

Voting members: Any person who has a baccalaureate degree and holds an official position in an agricultural college, experiment station, or federal or state department of agriculture in the United States or Canada, is eligible to membership. Other applicants may be admitted by vote of the executive committee.

Associate members: Any person not eligible to voting membership will be eligible to associate membership upon vote of the executive committee. Associate members shall not vote and will present papers only at the request of the program committee.

ARTICLE IV

Meetings shall be held annually at such time and place as may be designated by the Executive Committee, unless otherwise ordered by the Society.

ARTICLE V

The officers shall consist of a President, a Vice-President, a Secretary-Treasurer, and sectional chairmen to represent the subject-matter sections of the Society, who, together with the chairmen of the standing committees, shall constitute a Council to act upon all applications for memberships. These officers shall be elected annually by ballot.

ARTICLE VI

The Constitution may be amended by a two-thirds vote of the Society at any regular meeting, notice of such amendment having been read at the last regular meeting.

BY-LAWS

SECTION 1. The President and other officers shall perform the usual duties of their respective offices. The President shall also deliver an address at each regular meeting.

SEC. 2. There shall be a Committee on Nominations consisting of two members from each of the sectional groups who shall be nominated by the Executive Committee and elected by ballot at each annual meeting of the Society. It shall be the duty of this committee, at the following meeting to present a list of nominees for the various offices, committees (except the Nominating Committee), and representatives, and for the sectional chairmen, who shall be chosen in consultation with the sections.

SEC. 3. There shall be an Executive Committee consisting of the retiring president, who shall be chairman, the vice-president, the sectional chairman, two members elected at large for terms of two years each, retiring in alternate years, and the president and secretary-treasurer. This committee shall perform the usual duties devolving upon such committees and shall present at each annual meeting nominees for members of the nominating committee.

SEC. 4. The Committee on Nominations shall nominate referees and alternates upon special subjects of investigation or instruction, which may be referred to its consideration by the Society. The duties of these referees shall be to make concise reports upon recent investigations or methods of teaching in the subjects assigned them and to report the present status of the same.

SEC. 5. There shall be a Committee on Program, consisting of four (4) members, of which the Secretary shall be one. This committee shall have charge of the scientific activities of the Society, except as otherwise ordered by the Society.

- SEC. 6. The annual dues of the Society shall be four dollars.
SEC. 7. Ten members of the Society shall constitute a quorum.
SEC. 8. There shall be an editorial committee consisting of five members. One member shall be elected each year to serve for five years.
SEC. 9. There shall be a committee on sectional groups and membership.
SEC. 10. There shall be a committee on local arrangements.

SOCIETY AFFAIRS

RESUMÉ OF THE ANNUAL MEETING AT ATLANTIC CITY, NEW JERSEY, DECEMBER 29, 30, and 31, 1936

The thirty-third annual meeting of the Society was held at the Municipal Auditorium. There were 14 sections, including a joint session with the American Society of Plant Physiologists and the Physiological Section of the Botanical Society of America; and the Potato Association of America and the Vegetable Section of the American Society for Horticultural Science. There was also a symposium within the society on the topic of mineral nutrition. There were round table meetings on varieties, on extension, on education, and on vegetable varieties. The dinner and social evening in charge of the New Jersey workers in horticulture with Professor M. A. Blake as toastmaster, was held at Haddon Hall. Local arrangements were in charge of J. Harold Clark. The presence of Dr. Liberty Hyde Bailey and the showing of motion pictures of plant growth added materially to the completeness of the evening.

REPORT OF THE SECRETARY-TREASURER

On December 1, 1936, at which time the books of the society were closed for audit, there were 615 members of the society, a gain of 65 over last year. Money on hand was \$3,966.74 compared with \$3,460.66 a year ago, or an increase of \$506.08.

Following the action of the society at the St. Louis meeting, which called for a notice to be sent to members three months prior to the annual meeting asking for expressions of opinion on matters of policy in the organization and for suggestions regarding nominations, types of program, or other matters pertaining to the administration of the organization, 22 replies were received by the executive committee. Sixteen votes out of the entire membership were cast for officers, of which six were received by one person, four by another, and one each by six others. Many valuable suggestions regarding programs, and activities of the society were received, which were discussed carefully by the executive committee.

The society participated in the summer meeting of the American Association for the Advancement of Science at Rochester, New York. Dr. H. C. Thompson of Cornell University acted as chairman of the committee and arranged a joint program with the American Society of Plant Physiologists and the Physiological Section of the Botanical Society of America. A program of papers was given at the University of Rochester on June 17, and a trip was made to the New York State Experiment Station at Geneva, and to Cornell University at Ithaca on June 18.

Respectfully submitted,
H. B. TUKEY, *Secretary-Treasurer*

BUSINESS ENACTED AT THE ATLANTIC CITY MEETING

FORMATION OF THE SOUTHERN STATES SECTION

It was voted to approve the formation of a Southern States Section of the American Society for Horticultural Science, as recommended by Dr. J. C. Miller of Louisiana State University.

REPORT OF THE NOMINATING COMMITTEE

In its report the Nominating Committee submitted the names of officers and committees as shown on page ix of these Proceedings. The secretary was instructed to cast the vote of the Society for the officers and committees as nominated, and their election was declared.

REPORT OF RESOLUTIONS COMMITTEE

Cooperation of a high order has been characteristic of relations with several agencies in connection with this meeting. To acknowledge our indebtedness, we offer the following resolutions:

Resolved, that we express our appreciation to the American Association for the Advancement of Science for the finest cooperation on arrangements that we have had in several years. We wish to mention particularly Dr. H. B. Ward and Mr. Sam Woodley.

Resolved, that we extend our thanks to the Chamber of Commerce of Atlantic City, particularly to Mr. A. H. Skean and Mrs. Adams for their help in making arrangements for the meetings, also to the management of Haddon Hall for their fine cooperation.

Resolved, that we commend most highly the work of the New Jersey Horticulturists, Professor M. A. Blake, Dr. J. H. Clark, Dr. C. H. Connors and Dr. O. W. Davidson, in connection with the banquet.

Resolved, that we express to Dr. F. S. Howlett and the program committee how much their unusually successful efforts in arranging this program are appreciated.

In view of the fact that conditions in education are changing, be it *resolved*, that this society should give consideration to such changes and that the committee on education be continued, to report at the next annual meeting. (The Society voted to continue the same personnel on the committee, as follows: J. H. Gourley, chairman, R. J. Barnett, H. C. Thompson, W. P. Tufts, and G. F. Potter.)

R. A. VAN METER, *Chairman*

H. A. CARDINELL

C. H. CONNORS

C. P. CLOSE

H. A. JONES

TREASURER'S REPORT FOR 1936

Receipts

Dues (1936)	\$2,568.50	
Proceedings sold (includes bound volumes).....	1,062.65	
Extra pages purchased by authors.....	524.50	
Reprints and etchings sold.....	1,486.80	
	\$5,642.45	
Interest on money in savings account.....	55.86	
Balance on hand December 20, 1935.....	3,460.66	
Bills receivable, University of Arizona.....	24.68	
		\$9,183.65

Expenditures

Expenses of St. Louis meeting.....	\$ 99.15	
Humphrey Press, printing Proceedings.....	3,130.76	
Humphrey Press, printing programs.....	79.00	
Humphrey Press, letterheads, envelopes, labels, etc.	28.25	
Humphrey Press, reprints.....	496.82	
Humphrey Press, mailing volume 33.....	103.71	
Empire Photo Engravers, halftones and etchings..	549.32	
Secretary's office—includes clerical assistance.....	455.25	
Postmaster—stamps for mailing Proceedings, stamped envelopes, etc.....	210.02	
Proceedings purchased for resale.....	30.00	
Baldwin Paper Company, mimeograph paper.....	8.45	
Exchange on checks.....	1.50	
Total expenditures	\$5,192.23	
On hand December 15, 1936.....	3,966.74	
Bills receivable, University of Arizona.....	24.68	
		\$9,183.65

Respectfully submitted,
H. B. TUKEY, *Treasurer*

December 30, 1936

We have examined the accounts and found them to be in good order and correct; those keeping them are to be highly complimented.

H. L. CRANE
W. H. THIES
Committee

Pomologists Should Not Overlook the Varietal Problems in Fruits

By M. A. BLAKE, *New Jersey Experiment Station,
New Brunswick, N. J.*

DURING the first quarter of the Twentieth Century, horticulturists engaged in state and federal work were expected to have an intimate knowledge of the external characters of mature specimens of the common varieties of deciduous fruits. Many of them were authorities upon varietal identification and fruit judging. Some of these authorities upon fruit varieties also had an expert knowledge of the tree habit, vigor, hardiness, productiveness, and other plant characters of each variety. In other words, they were plant experts as well as mature fruit experts.

Variety testing was a leading or prominent project at nearly every state experiment station during the first 20 years of this century. From a modern point of view the work was of a somewhat elementary nature, a fact which was necessarily true of much of the Station work in the beginning and is true today in any new line of research. Variety collections were not always strictly rogued of varieties untrue-to-name and they did not always receive good pruning, spraying or cultural management because of limited funds, personnel, and other factors. Nevertheless, variety testing upon the old basis held an important place at the time and served certain definite important needs. The older horticulturists know that they would have been considered lacking in horticultural training by fruit growers if they could not identify the common commercial varieties of fruits. In fact, if an official horticulturist was ever to gain the confidence of the fruit growers of his state he was obliged to possess some practical knowledge of varieties and it is necessary today for anyone who deals with the industry in its broader phases.

About the time of the World War, commercial horticulture and horticultural research had made such advances in America that it became necessary for departments of horticulture in states where fruit production was a commercial industry to consider problems involving technical phases of plant metabolism, nutrition, structure and plant breeding. Biochemists, physiologists, botanists, and plant breeders have been added to the staffs of horticultural departments in recent years. It is not an exaggeration to state that horticultural research in America has made greater advances in the last 10 years than it made in the previous 20. This fact can be viewed with much satisfaction. Research activities, however, tend to become concentrated into one or more lines in a department and even among institutions for a period. Concentration of personnel and means is necessary to solve some of our problems but therein lies the danger that departmental activities may become too limited in their scope.

In many of the states today, the horticultural department or division of the college, university, and station is responsible for three classes of service in horticulture, namely, resident teaching, extension teaching, and research. In states where a commercial fruit industry exists and

especially where the college and station receive state funds, the horticultural staff is looked to for leadership in the solution of the fruit problems of that particular state. What is the basic objective of all of our research with fruits? It is not to enable us to grow better varieties of fruits more efficiently for the benefit of growers and consumers? How else can public financial support be justified.

We have long since passed the stage in commercial fruit growing in America where we just grow apples as apples. We now grow varieties of apples. Production, transportation, marketing, processing, and consumption are all intimately concerned with varieties. Any fundamental principle of plant growth discovered by the highest type of research must be interpreted and applied upon a varietal production basis by someone before it can really serve our basic objective. This is a fertile field for a pomologist today. Bits of research even of great individual merit placed just outside laboratory doors do not improve the industry. Someone must take these units and measure, modify, and fit them into the established procedure of production before practical benefits may be realized. This is a continuous task and it is rapidly increasing in scope and complexity with modern changes in the mode of living. There is every indication that we are rapidly approaching a time when there will be an urgent demand for horticulturists who can broadly and keenly analyze and evaluate all of the worthwhile new findings and data in terms of practical application to the industry. Such a man will require broad training and some years of experience and will be obliged to maintain close contact with research as well as with the industry. There is no need for a good pomologist to try to graft himself over into only a fair botanist or chemist in order to find a field worthy of the highest mental attainments.

What has all this to do with modern varietal problems and what are some of them? Economists will agree that one of the costly features of tree fruit production today is the planting, care, and removal of trees of unprofitable varieties. Since production is developing in larger and larger units the losses from such mistakes tend to become more costly. The commercial life of a variety is also becoming increasingly shorter with the times. Processors of fruit, juice manufacturers, bakeries, exporters, storage men, chain stores, restaurants, hotels, and all users of fruit are becoming more and more quality conscious and thus variety conscious.

The grower must meet these changing demands or his orchards will be unprofitable. Apple growers must be able to learn much more about the characteristics of new varieties before they plant them in the future or severe losses are certain. In other words, modern varietal information today should be far in advance of the old standards.

More information is needed upon the response of varieties to seasonal temperatures. Some varieties can function successfully at lower temperatures in spring than others as, for example, Baldwin as compared to Stayman (1). Certain varieties of summer apples respire carbohydrates so rapidly at high temperatures that they become worthless in a warm climate.

Anoka is described as a promising early apple which attains some red color in the Dakotas. At maximum daily temperatures of 85 to 95

degrees F in New Jersey the flesh breaks down before the fruit is fit to be sold. Some varieties of apples, such as McIntosh, do not attain best color, texture, and quality if the mean daily temperature much exceeds 60 to 62 degrees F during the last 2 weeks of ripening. Some varieties of peaches, for example, Golden Jubilee, develop fruits of good size with well rounded cheeks in a moist, fairly cool environment but smaller fruits with flat cheeks in a hot, dry climate.

A variety of fruit may be resistant to low winter temperatures in one region but not in another. The Stevens peach is regarded as quite hardy in bud in some situations north of New York City but is not particularly so to the south of it. What are the fundamental factors concerned in the many forms of varietal hardiness?

Some varieties of apples tend to be over-vegetative under certain temperature and moisture conditions; others are biennial in bearing. Some varieties of apples are more susceptible to acid soils and calcium deficiencies than others. Some varieties of peaches are higher in catechol tannin in some environments than others.

These problems not only involve the field of the plant breeder, but also those of the biochemist, the plant physiologist, the botanist and last but not least, the varietal specialist. When regarded seriously they are not simple varietal test problems but require the highest type of present day research skill for solution.

It is also clear that information upon varieties needs to be placed upon a higher plane to meet modern demands. Apple growers are quite concerned at present over the future market demand and price of apples. The variety question is a very important phase of this problem.

The development of new varieties of deciduous fruits is rapidly becoming centered in the various state and federal research agencies. These units have the opportunity to set up modern standards and tests which a new variety must meet in order to attain recognition and approval for introduction. There is also the opportunity to set standards of varietal descriptions to prevent confusion and misleading impressions.

Varietal improvement is one of the most efficient means of decreasing cost of production as well as increasing edible quality. It is a form of progress which particularly appeals to growers and is therefore a field in which they are too often misled by exaggerated or unproven claims for varieties.

This raises a pertinent question. Is the responsibility of a horticultural department of a state college and station to its own state fruit industry discharged when it develops an improved variety and merely sets it outside on the institutional door step? Supposedly, the new variety or the new strain or selection was developed to meet some need in the industry of a certain state or region. The problem then is not really solved until the new plant has been propagated and distributed to the growers and they have been able to benefit from its development.

At present the country is becoming more and more progress conscious as measured in terms of economic development. Varietal improvement will come to be measured more and more by its actual contribution in an economic way. There should be no weak or missing

links between our horticultural departments which are developing improved varieties of plants and the producers of the state.

We should jealously guard our opportunities to render practical service upon modern varietal problems and to assume the leadership in establishing modern standards for varietal description, evaluation, and registration for plants which we originate and develop.

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A Hetro-Chimeric Apple Sport and Its Vegetative Progeny

By V. R. GARDNER, *Michigan State College, East Lansing, Mich.*

ABSTRACT

This material will be published in full elsewhere.

A DESCRIPTION of a whole tree sport, apparently of the Northern Spy, occurring in a Michigan orchard. This tree produces fruits of great diversity in size, color, shape and maturing season, though all of them resemble Northern Spy in flesh character. Incidental to the use of a large number of cions from this tree some years ago for top grafting purposes, there have been segregated out from the parent a considerable number of distinct strains or types, enough different from each other to be regarded as varieties.

The External Characters of Green Fruits of the Peach are Valuable Aids in Varietal Identification

By H. J. SEFICK and M. A. BLAKE, *New Jersey Agricultural
Experiment Station, New Brunswick, N. J.*

CLASSIFICATIONS of peaches and nectarines based upon external characteristics such as flesh color, pubescence of skin, leaf glands, adherence of flesh, and flower size were made as early as 1818. Gregory (1) reviewed the early literature on classification of peaches quite thoroughly in 1915. Upshall (2) and Shoemaker (3) used the scarcity or abundance of yellow pigment in the leaves in their classification. Blake (4) showed that variations in size or shape of petals, calices, sepals, and receptacles of the flowers are useful in identification. To our knowledge there is no published record of the use of the green fruit of the peach during the pit hardening stage of development as a means for the separation of varieties.

It is of increasing economic importance to be able to identify not only the ripe fruit of varieties, but also trees in nursery and orchard. It is essential that commercial growers learn as soon as possible whether blocks of trees are true-to-name and every practicable means of distinguishing one variety from another should be investigated. Development and introduction of new varieties and types makes a continuous study of varieties imperative.

THE RELATION OF FORM OF GREEN FRUIT TO RIPE FRUIT

There is a close resemblance in general form between small green fruits at the pit hardening stage and mature fruits. This is because the pit largely determines the external form of the fruit. For example, Carman in New Jersey has a round fruit at the pit hardening stage and a round fruit at maturity. However, there are certain minor form differences between green and mature fruits. In ripe fruits the flesh extends farther above the stem attachment forming a cavity. Green fruits are somewhat flatter in suture view than mature fruits because, in ripening, peaches tend to increase more rapidly in cheek diameter than in longitudinal diameter.

Green fruits as well as ripe fruits vary in form according to climatic factors. Fruits tend to be longer and more pointed when temperatures are high at the beginning of the fruit development period (5). Fruit forms described for New Jersey might not be characteristic in all details for the same varieties grown elsewhere. Nevertheless, round peaches in New Jersey will be round relative to other varieties in other regions. It is necessary that authorities on varietal identification become familiar with these variations.

GREEN FRUITS AT PIT HARDENING STAGE

Green fruits at the pit hardening stage were selected for study because, during this period of development, growth of the fruit is very slow. Observations at New Brunswick in 1930 (6) showed that the fruits of Elberta increased in average diameter at a rate not exceeding .007 inches per day.

A total of 122 named and 73 unnamed varieties out of the large collection growing on the grounds of the New Jersey Experiment Station was studied. Five large, well developed, green fruits, typical of each variety, were selected. Measurements of the three diameters were made and form was studied in detail. The period from June 27 to July 11, 1936 was required to make the observations on this large number of varieties. Some changes in size would occur during this period but not sufficient to modify varietal differences in form.

GENERAL FORM

Neither a small green peach nor a ripe fruit is symmetrical in form in all respects. They vary somewhat according to the aspect from which they are viewed. For all practical purposes only the cheek aspect and the ventral suture aspect were considered as being worthy of attention.

The cheek view form of a variety at the pit hardening stage is likely to vary somewhat from the suture aspect. Nevertheless, it was found possible to use the same general form terms to classify green fruit from either aspect.

The following nine terms were found to be adequate to classify the fruits according to general form, namely: 1, Round; 2, Oval; 3, Ovate; 4, Obovate; 5, Oblique; 6, Oblate; 7, Round-Truncate; 8, Winged; and 9, Peento. Fruits which do not conform exactly to these terms may be described by combinations of these terms and such adjectives as broad, flat, oblong, and conic.

RELATION OF BASE AND APEX TO GENERAL FORM

Both the base or stem end, and the apex may modify the general form. The base may vary from distinctly round, as in Early Wheeler, to flat, as in Marigold. The following series of five terms have been set up as a standard for base classification: 1, Round; 2, Flat; 3, Slightly flat; 4, Tapering; and 5, Necked.

The distal end of the peach fruit is commonly termed the apex. In this paper, the term is employed to mean the body of the fruit at the distal end and does not apply to the tip which is described and classified separately from the apex. The following three terms were selected as a standard for describing the apex, namely: 1, Flat; 2, Round; and 3, Pointed.

The apex tip or protuberance at the apex may be classified according to the following terms: 1, A point (depressed or not depressed); 2, Mucronate (depressed or not depressed); 3, Slightly prominent; 4, Prominent; 5, Mammiform; 6, Beaked. Each in turn may be modified by the three terms: a, straight; b, curved; and c, hooked.

VARIETIES EXEMPLIFYING THE TERMS RELATING TO FORM OF GREEN FRUITS

Individual varieties whose green fruits are representative of the terms illustrated in the diagrams in Fig. 1 are respectively: 1, Early Wheeler; 2, Marigold; 3, Columbia; 4, Dwarf Blood; 5, J. H. Hale; 6, Belle; 7, Briggs Early May; 8, Smock; 9, Peento; 10, Mountain Rose; 11, Duke of York; 12, Sargents; 13, St. John; 14, Mountain

Rose; 15, Primrose; 16, Hope Farm; 17, Iron Mountain; 18, St. John; 18a, Marigold; 19, Primrose; 19a, Japan Golden Giant Cling; 20, Crosby; 21, Slappey; 22, Chinese Blood; and 23, Estella.

COMBINATIONS OF CHARACTERS

Since the green fruits of many varieties of peaches are described by combinations of the characters illustrated in Fig. 1, a few examples are given.

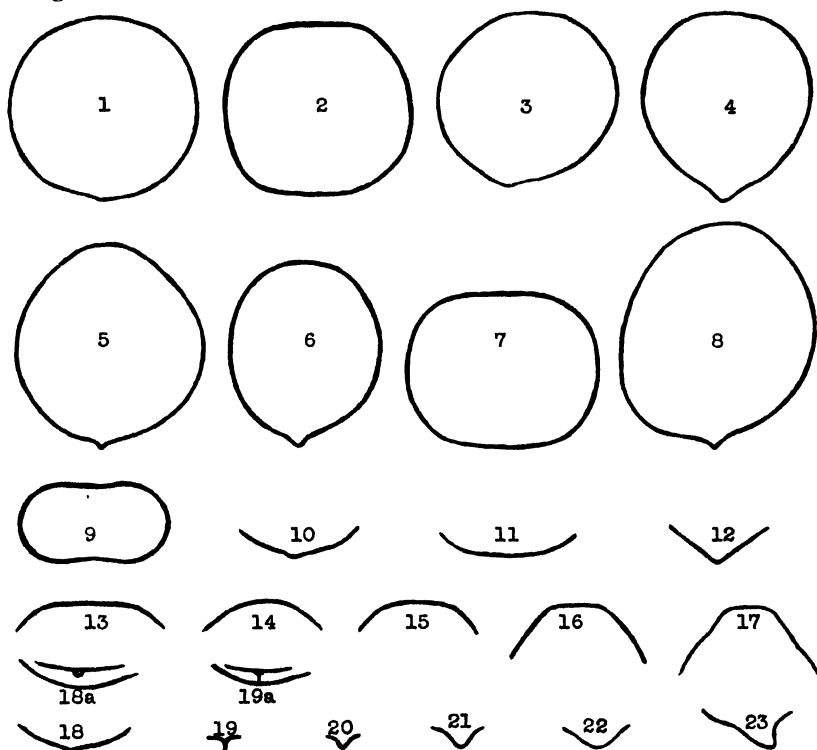


FIG. 1. Diagrams of Green Fruit Characters of the Peach.

General Form— 1. Round, 2. Round Truncate, 3. Oblique, 4. Ovate, 5. Obovate, 6. Oval, 7. Oblate, 8. Winged, 9. Peento.

Apex Form —10. Round, 11. Flat, 12. Pointed
Base Form —13. Flat, 14. Round, 15. Slightly Flat, 16. Tapering, 17. Necked.

Apex Tip —18. A Point, 18a. A Point (depressed)
19. Mucronate, 19a. Mucronate (depressed)
20. Slightly Prominent, 21. Prominent,
22. Mammiform, 23. Beaked.

Three varieties which have oval green fruits differ from each other in detail as follows: Elberta is broad-oval to oval-obovate, with a slightly tapering base and a slightly prominent apex tip. Belle is distinctly oval with a slightly flat base and a slightly prominent apex tip. Pallas is oval with a slightly flat base and a beaked apex tip.

Three varieties whose green fruits are round in form differ from each other in detail as follows: St. John is flat at the base with the apex tip a point, not depressed. Carman is round at the base with the apex tip a point, slightly depressed. Early Crawford is round-winged, round at the base and with the apex tip slightly prominent and curved.

Space in this paper does not permit similar descriptions and classifications of all the varieties studied.

PUBESCENCE AND SIZE OF FRUIT

Marked differences occur in pubescence at pit hardening stage, ranging from smooth short haired varieties like Candoka and J. H. Hale to heavily pubescent varieties like Chili.

The range in size of the fruits studied at pit hardening stage was sufficiently wide to make relative size a valuable character to combine with form for identification and classification. Between the varieties studied there was an extreme difference in size of almost 1 inch in each of the three diameters. The extreme range between the varieties in three diameters was actually 1.23 to 2.18 inches in length, 1.04 to 1.91 inches in suture, and 0.93 to 1.83 inches in cheek.

On the basis of data secured at New Brunswick during the season of 1936, the varieties have been arranged into five groups according to length of which the following are examples:

1. Very small: under 1.39 inches, Sleeper's Dwarf and Mignonne.
2. Small: 1.40 to 1.59 inches, as Duke of York and Pallas.
3. Medium: 1.60 to 1.79 inches, as Chinese Cling and Slappey.
4. Large: 1.80 to 1.99 inches as Elberta and Marigold.
5. Very large: 2.00 inches and above, as Cumberland and White Hale.

Some of the very early maturing varieties such as Mayflower will be in a more advanced stage of development (7) than mid-season and late varieties. They will therefore be larger in proportion to the size which they finally attain at maturity than the others.

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Apple Breeding Studies II. Fruit Shape¹

By A. N. WILCOX and ERNEST ANGELO, *University of Minnesota, St. Paul, Minn.*

THE apple seedlings upon which the character of fruit shape was studied were grown from the seeds of controlled crosses made from 1918 to 1920. The method of planting and the general methods followed in recording the characters were given in the previous publication (1) on fruit color. In general the same progenies were used in both studies, but with some variations in the number of seedlings due to the fact that slightly more extensive notes were taken on fruit color than on fruit shape. Several populations were not included in the present study, due to their small size, and several were added which had not been considered in the previous study.

The desirable procedure of recording actual shape measurements, which were possible in the first years of fruiting, soon had to be abandoned because of the loss of assistance. Consequently the fruits were classified in arbitrary categories. Whenever possible the fruit shape of a seedling was placed in one of three principal classes; oblate, round and oblong. Occasionally it seemed necessary to place it in one of the intermediate groups. When the data obtained over the several years were summarized, a seedling was classified as belonging in one of the three principal categories for fruit shape only when it appeared in that category at least two-thirds of the years in which the notes were taken. When, as occurred in a number of cases, a seedling had been recorded as round in as many years as oblate, it was placed in the intermediate category of round-oblate.

This method of classification of the character of fruit shape has certain obvious shortcomings, among which is the fact that the resulting distribution does not approach a normal curve and hence does not possess the characteristics upon which the calculation of standard error is predicated. It is possible, however, to compare selected progenies by the χ^2 method if the precaution is taken to condense the classification in such a way as to equalize the number of categories in the populations being compared and to assure that no category is occupied by a number too closely approaching zero.

As in the previous study, the frequency distributions of the several populations of each cross were examined to permit the elimination of any populations which might not be comparable with other populations in the same cross. On this basis it was necessary, as before, to eliminate one population labeled Oldenburg x King David.

PROPORTIONAL FRUIT SHAPE

The data on fruit shape are summarized in Table I. For convenience in comparing the crosses, the per cent of seedlings rather than the number is given in each category. The average shape value, which serves as an index of shape, was calculated from the actual numbers

¹Paper No. 1484 of the Scientific Journal Series of the Minnesota Agricultural Experiment Station.

TABLE I—SUMMARY OF FRUIT SHAPE IN APPLE PROGENIES

Parentage	Number of Seedlings	Oblate (Per Cent)	Round-Oblate (Per Cent)	Round (Per Cent)	Round-Oblong (Per Cent)	Oblong (Per Cent)	Average Shape Value	Conic (Per Cent)
Grimes Golden x Oldenburg	171	27	11	51	4	7	2.5	8
Okabena x Delicious	27	37	—	59	—	4	2.3	11
Oldenburg x Black Ben Davis	21	33	10	57	—	—	2.2	5
Oldenburg x Delicious	184	39	10	45	2	5	2.2	7
Black Ben Davis x Oldenburg	29	34	17	45	—	3	2.2	14
Delicious x Okabena	43	42	12	40	2	5	2.2	14
Charlamoff x Delicious	43	44	7	47	—	2	2.1	9
Delicious x Oldenburg	36	50	14	31	—	6	2.0	6
King David x Charlamoff	24	50	17	33	—	—	1.8	8
Oldenburg x King David	34	50	21	26	3	—	1.8	0
Oldenburg x Grimes Golden	70	59	9	31	—	1	1.8	4
Jonathan x Oldenburg	372	62	9	27	1	1	1.7	2
King David x Oldenburg	188	64	5	30	—	1	1.7	3
Winesap x Oldenburg	30	60	13	27	—	—	1.7	0
Lady x Wealthy	23	70	—	26	—	4	1.7	0
Okabena x Oldenburg	42	68	7	23	—	2	1.6	5
King David x Delicious	42	67	5	29	—	—	1.6	2
Grimes Golden x Wealthy	21	67	10	19	5	—	1.6	0
Jonathan x Patten Greening	94	62	16	12	—	—	1.6	3
Wealthy x Okabena	46	67	13	20	—	—	1.5	4
Jonathan x Hibernial	40	64	18	18	—	—	1.5	0
Jonathan x Okabena	24	76	8	16	—	—	1.5	0
Okabena x Grimes Golden	31	81	6	10	—	3	1.4	3
Wealthy x Wolf River	23	78	9	13	—	—	1.4	0
Patten Greening x Wolf River	50	82	2	18	—	—	1.3	4

falling in each category, the categories being numbered from 1 for oblate to 5 for oblong. The crosses are listed in order of rank with respect to this value. The per cent of seedlings with conic fruit is given independently in the last column.

In order to obtain some criterion of the significance of the data on proportional fruit shape, or oblateness, the χ^2 test of independence was applied to the various crosses, using four-fold tables in which the oblate and round-oblate totals were placed in one column and the round, round-oblong and oblong totals in the other. The differences were accepted as significant when the χ^2 was high enough to reduce the corresponding value of P below .05.

On this basis all differences exceeding .7 in average shape value are significant, as are many lesser differences. Thus Grimes Golden x Oldenburg is significantly higher than Oldenburg x Delicious as well as all other crosses below 2.1. Okabena x Delicious is also appreciably higher than all crosses below 2.1. Oldenburg x Black Ben Davis and Oldenburg x Delicious are higher than Oldenburg x King David and all lower ranking crosses. Black Ben Davis x Oldenburg significantly exceeds Jonathan x Oldenburg and both the former and Delicious x Okabena exceed all crosses below 1.7. Charlamoff x Delicious ranks above Jonathan x Patten Greening and all lower crosses; King David x Charlamoff outranks Jonathan x Hibernial and lower crosses, Jonathan x Oldenburg outranks Jonathan x Okabena and lower crosses; and Oldenburg x Grimes Golden and King David x Oldenburg significantly outrank only the lowest cross.

The conclusions which can legitimately be drawn from data of this kind are necessarily limited. It is apparent, however, that the tendency toward relative length and away from relative oblateness is transmitted most consistently by the parents Delicious and Black Ben Davis and is also transmitted in a high degree in certain cases by Grimes Golden. The parents which appear to be effective in the other direction include Jonathan, King David, Patten Greening, Wealthy and Wolf River. Oldenburg probably belongs somewhere between these two groups of varieties.

Conic fruit:—A summary of the data on conic fruit is presented in terms of per cent in the last column of Table I. Due to the fact that appreciable numbers of conic fruits appeared in only a few of the crosses, a statistical comparison is permissible with only a few of the populations. Using the same criterion of independence as before, it is possible to say that Delicious x Okabena, Grimes Golden x Oldenburg and Oldenburg x Delicious produced a significantly higher proportion of seedlings with conic fruit than King David x Oldenburg and Jonathan x Oldenburg.

The more frequent occurrence of conic fruit in the progenies with high average shape value than in the more oblate progenies bears out what was more strikingly shown in the original data. Of all seedlings with fruit in the oblate class, less than 1 per cent were also conic; in the round-oblate class, 4 per cent; round, 8 per cent; round-oblong, 32 per cent; and oblong, 15 per cent. The use as parents of Delicious and Black Ben Davis, with their conic and relatively longer shape,

contributes slightly to this association. Some of it may also be due to the greater difficulty of observing the conic shape in oblate apples.

Reciprocal crosses.—The reciprocal crosses of several parental combinations are available for study: Black Ben Davis with Oldenburg, Delicious with Okabena, Delicious with Oldenburg, Grimes Golden with Oldenburg, and King David with Oldenburg. In addition, data are available on Oldenburg x Jonathan and Grimes Golden x Okabena which are not included in Table I because of the small number of trees, 18 and 15, respectively. The reciprocals of these crosses do appear, however. The χ^2 test of independence was applied to the reciprocal matings in each of these seven combinations with respect to the character of proportional fruit shape. In six of them no significant difference was found. In the case of Grimes Golden and Oldenburg the differences between the reciprocals gives a χ^2 sufficiently high so that the corresponding value of P is well below .01, indicating a very significant difference.

This difference coincides with the difference in fruit color reported in the previous study. In that case 99 per cent of the seedlings of Oldenburg pollinated with Grimes Golden produced red striped fruit, the remaining 1 per cent lacking red, while only 48 per cent of the seedlings of Grimes Golden x Oldenburg produced red striped fruit. The present case shows the same trend in the progeny toward the type of the maternal parent. The average shape value of 2.5 found in the progeny of Grimes Golden x Oldenburg approaches the shape of Grimes Golden, which is round or round-oblong, while the value of 1.8 in Oldenburg x Grimes Golden approaches the shape of Oldenburg, which is oblate.

In fruit shape as in fruit color these characteristics of the progeny are consistent in all three populations of Grimes Golden x Oldenburg and in all three populations of Oldenburg x Grimes Golden. As would be expected, however, from the nature of the character and the methods of taking the notes, greater variation is found with respect to fruit shape than with respect to fruit color.

Inasmuch as the three Grimes Golden x Oldenburg crosses were made in three different years and two Grimes Golden trees were employed, the similarity of the three populations of this cross removes any probability of a mistake in that material. The three Oldenburg x Grimes Golden crosses, on the other hand, were all made in the same year and upon three different Oldenburg trees. The similarity of the three populations of this cross removes any probability that the maternal trees were not Oldenburg, but fails to eliminate the slight possibility that some pollen other than Grimes Golden was used on all of them.

It is desirable to point out again that this phenomenon should be studied further, both to establish whether it occurs without any possibility of mistake, and, if so, to investigate its cause. There are several conceivable explanations. It is hoped that the further study of available material may shed additional light on the problem.

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Material for the Breeding of Winter Hardy Pears¹

By A. N. WILCOX, *University of Minnesota, St. Paul, Minn.*

THE breeding of pears at the University of Minnesota Fruit Breeding Farm for the purpose of developing desirable varieties which would possess great winter hardiness has made gradual progress since its inception in 1908, when seeds of hardy pears were obtained from northern China. Since that time numerous introductions, both of varieties and seeds, have been made and the resulting trees exposed to natural winter conditions without artificial protection, and further work along the lines of selection, hybridization, and inbreeding has been conducted.

At present the collection contains more than 50 varieties of each of which several trees have been grown, so that some conclusions can reasonably be drawn concerning their relative hardiness. About one-fourth of these have been grown for more than 10 years, during which the original trees, if sufficiently hardy, have attained large size and, in some cases, trees propagated from the first trees have been fruiting for several years. Another one-fourth have been grown as orchard trees for more than 5 years and have been fruiting, in most cases, for 3 years. The remaining varieties have been grown only from 3 to 5 years, and have borne fruit in only a few cases.

The greatest confidence should obviously be placed in the conclusions drawn from the oldest group. Nevertheless, the observations on the younger groups may also be very valuable due to the severe weather conditions which have occurred during the recent years and to which they have consequently been exposed. A sudden and severe freeze in the autumn of 1934 was followed by a winter in which exceptionally low temperatures occurred. Some varieties were rather severely injured. During the winter of 1935-36 even lower temperatures occurred, and during the latter part of the winter the trees were exposed to extreme changes of temperature resulting in the most severe injury to fruit trees in many years. All degrees of injury occurred in the pears. This injury was usually of the sunscald type. In some cases the damage was apparent as soon as growth started in the spring, in other cases it appeared later in the summer. Many trees were completely killed, others suffered a characteristic killing on all except the north side of the tree, and a few varieties were apparently uninjured.

A summary of the observations on winter hardiness is given in Table I. The first degree of hardiness includes the varieties which have never suffered more than a slight killing of the tips of the smallest branches, the second degree includes the varieties which at some time have suffered considerable branch killing without very serious interruption of the growth or continuity of fruiting, and the third degree of hardiness includes the varieties which have been very seriously injured at some time to the extent that the entire trees or the major scaffold branches have been killed. Recognition was given in preparing these data to the importance of comparable locations and exposures.

¹Paper No. 1483 of the Scientific Journal Series of the Minnesota Agricultural Experiment Station.

TABLE I—RELATIVE WINTER HARDINESS OF PEAR VARIETIES AT THE MINNESOTA FRUIT BREEDING FARM

Relative Hardiness	Varieties Tested 10 or More Years	Varieties Tested 5 to 10 Years	Varieties Tested 3 to 5 Years
First Degree	Minnesota No. 3 Minnesota No. 4 Minnesota No. 5 Minnesota No. 6 Minnesota No. 7 Phiel Seedling "Russian Sand Pear" Sapronsky	Borgman Seedling Cepe Zum Mur (Russian) Patten No. 5 Patten No. 1204 Patten No. 1205 Pushken	<i>P. communis</i> , S. P. I. 47093, <i>et al.</i> <i>P. ovodea</i> , S. P. I. 44051 <i>P. ussuriensis</i> , S. P. I. 44235, 44237, 44275, <i>et al.</i>
Second Degree	Patten Simola Chang	Patten No. 1200 Tait No. 1 Tait No. 2	<i>P. betulafolia</i> , S. P. I. 39547 <i>P. Breitschneideri</i> <i>P. communis</i> , S. P. I. 33207, <i>et al.</i> <i>P. phaeocarpa</i> , S. P. I. 32741, 39541, 43185 <i>P. sp.</i> S. P. I. 44276 <i>P. sp.</i> "Favorite", S.P.I. 33207 <i>P. ussuriensis</i> , S. P. I. 47094, 55967, 55970 Van Fleet Hybrid, S.P.I. 43443
Third Degree	Mendel Parker	Beierschmitt Patten No. 1206 Tait No. 4	<i>P. calleryana</i> , S. P. I. 47261 <i>P. chinensis</i> <i>P. phaeocarpa</i> , S. P. I. 64229 <i>P. sp.</i> "Surprise", S. P. I. 45901 <i>P. sp.</i> S. P. I. 46566, 56012, 64223 <i>P. sp.</i> Van Fleet Hybrid, S. P. I. 55805 <i>P. ussuriensis</i> , S. P. I. 46587

Most of the varieties listed in this table are not generally well known. The Phiel seedling, Borgman seedling, and Mendel came from private growers in Minnesota, the Patten and other Patten seedlings from the Iowa Agricultural Experiment Station, the Beierschmitt from a private grower in Iowa, and the Tait seedlings from Ontario. The Pushken is a Russian variety obtained in Manitoba. The Parker, formerly known as Minnesota No. 1, was introduced by the Minnesota Agricultural Experiment Station.

The Minnesota numbered seedlings are particularly interesting from the breeding point of view. Although the parentage of Minnesota No. 3 and No. 4 is unknown, these seedlings are supposedly of Asiatic descent. No. 3 possesses exceptional hardiness in Minnesota, North Dakota, and even in Saskatchewan, and bears heavy crops of rather small fruit with good dessert quality. No. 5, 6 and 7 are listed in the early records merely as seedlings of "King Karl x Sand Pear". They

are presumably seedlings of the European variety, König Karl von Württemberg pollinated by an Asiatic species, possibly the "Russian Sand Pear" listed in Table I. They are fully as hardy as the hardest Asiatic species and varieties now in the collection, and are probably considerably harder than the average of their parents. The original seedling trees of all three are large, vigorous and healthy, and produce heavy crops of fruit which are, unfortunately, of rather poor quality. The fruit of No. 5 is medium large, nearly 3 inches long on the average, while the fruit of the others is small. Nos. 6 and 7 have never been found with blight in spite of the fact that nearby trees of some other varieties have been very severely blighted in certain seasons. Artificial inoculations of these as well as of other varieties in the collection have been followed by weather unfavorable to development of the disease and have been unsuccessful.

In addition to the varieties listed in Table I, there are several surviving varieties with which comparisons could not safely be made. Many others which have been planted and lost might have yielded valuable information had not many or most of them been propagated on tender rootstocks before they were received. It is the present practise to propagate new introductions on stocks of known hardiness. Thus several collections of varieties received in the spring of 1934 were topworked on the hardest Asiatic seedlings available. Although the varieties so propagated have been exposed to only two winters, great differences in the hardiness have already been observed, and nine varieties obtained from Norway and Sweden have shown no injury whatever.

Progress in breeding pears for hardiness combined with other desirable characters is necessarily slow. There has usually been poor survival of seedlings of *Pyrus communis* crossed with Asiatic forms, due to low average hardiness in the seedling populations. Several exceptionally hardy seedlings of such crosses have, however, been obtained. The best survival and the highest average hardiness have been found in what may be called the F_2 of these crosses, obtained through the open pollination of such hybrids as the Minnesota seedlings. More than 500 of these second generation seedlings are now being grown, some of which are already bearing fruit.

Can Bees Retain Pollen of Early Apple Varieties for Effective Pollination of Later Blooming Sorts?

By L. P. LATIMER, *University of New Hampshire, Durham, N. H.*

THE question is often asked by apple growers whether bees may obtain pollen from an early blooming variety and keep it to serve in pollinating a later blooming sort (several days often intervening between the last bloom of the former and the opening of blossoms on the latter). In 1935, four 16-year-old McIntosh trees were each enclosed in a cheesecloth cage a short time before coming into bloom. The experiment was divided into four parts:

1. Bees not having been previously exposed to apple blossoms, placed in cage with McIntosh tree, thus effecting self-pollination.
2. Bees taken from orchard of open blossoms and placed in McIntosh cage at night.
3. Same except that bees were stored 48 hours at 45 degrees F and then placed in McIntosh cage.
4. Same except that bees were stored at 45 degrees F for 96 hours before placing in McIntosh cage.

It should be mentioned that bees were placed in all cages on the same day.

In 1936, the same four trees were again enclosed in cheesecloth cages and experiments conducted as follows:

1. No bees placed in McIntosh cage (self-pollination)
2. Same as (1) of 1935
3. Same as (3) of 1935
4. Bees not exposed previously in orchard but put in McIntosh cage together with a liberal supply of blossoming Northern Spy branches to serve as source of pollen for cross-pollination.

The results are given in Table I.

TABLE I—POLLINATION BY BEES WITHHELD FROM APPLE BLOSSOMS FOR DIFFERENT LENGTHS OF TIME

	Blossoms Set (Per Cent)		Number of Seeds Per Fruit		Number of Empty Seed Cavi- ties Per Fruit		Lopsided Fruits (Per Cent)		Trees	
	1935	1936	1935	1936	1935	1936	1935	1936	1935	1936
Check (no bees)	—	1.7	—	1.3	—	3.8	—	72	—	No. 49
Check (bees)	3.1	1.3	2.4	1.5	3.0	3.5	83	78	No. 145	No. 145
Bees away from flowers 4 days	2.3	—	2.6	—	2.7	—	77	—	No. 139	—
Bees away from flowers 2 days	3.7	3.9	2.7	1.7	2.8	3.4	69	76	No. 98	No. 98
Bees away from flowers over night.....	6.1	—	3.0	—	2.5	—	65	—	No. 49	—
Bees (Spy Bloss- oms in Cage)	—	8.7	—	3.1	—	2.0	—	60	—	No. 139

In 1936, there was no significant difference in set of fruit whether bees were in the cage to effect self-pollination or not. Apples in both cases contained about the same number of seeds. Seventy-two to 78 per cent of the fruits were lopsided to a considerable degree.

Where bees were kept away from apple blossoms for 4 days, the set of fruit was not improved over self-pollination. It is felt that what pollen the bees had obtained in the orchard, was either removed from the bee's bodies or was rendered unfit for pollination purposes.

Although keeping the bees away from apple blossoms for 2 days resulted in a poor set of fruit in 1935, in 1936 approximately twice as much fruit was set on a McIntosh tree under similar conditions. On the other hand, the seed content of the resultant fruits was in both years nearly identical with that of apples setting from self-pollination. It is possible that conditions in 1936 were more unfavorable for self-pollination than in 1935 and there was enough viable pollen left on the bees to do some good. When the bees were removed from the orchard at night and placed immediately in a cage (1935) the set of fruit resulting from their activity was double the amount resulting from self-pollination. There seemed also to be a slight increase in the average number of seeds present in the fruit.

When Northern Spy blossoms were available to the bees (1936), about five times as much fruit was produced as with self-pollination, enough for a satisfactory commercial crop. In this case the seed count was doubled.

It might be said that the bees were not working under natural conditions in the cages and that their performance under these conditions would not be typical of activity under conditions of free flight.

Although the bees seemed to be flying about actively in the cages and were seen to visit the blossoms, it so happened that when Northern Spy branches were furnished and a commercial set of fruit was obtained the seed content of the apples was only one-third of that obtained ordinarily in McIntosh under conditions of open orchard pollination and in hand-cross pollination tests. This indicated the following possibilities:

1. Under the cages only a small percentage of the bees may have emerged from the hive compared to free orchard conditions, hence reducing the amount of work done.
2. Bees may not have visited the Northern Spy branches in the tubs freely enough, hence reducing the chances of all McIntosh stigmas receiving Spy pollen.
3. Bees may have visited McIntosh blossoms, first becoming covered with the pollen so that any Northern Spy pollen with which they may have come in contact would be diluted to some extent.
4. Bees visiting Spy blossoms might not have visited the McIntosh blossoms.

It seems evident that some Spy pollen reached a large number of McIntosh flowers but probably just enough to cause the fruit to set with a minimum number of seeds. Inadequate pollination is also indicated by the number of empty cavities in the fruit and the large per-

centage of lopsided fruits, 60 per cent, whereas with good cross pollination not more than 5 or 10 per cent of the fruits are ordinarily lopsided in McIntosh.

However this may be, it seems certain that pollen gathered by bees two or more days before they visit flowers we desire to pollinate, is of little or no value for pollination purposes.

Papaya Pollen Germination and Storage

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ABSTRACT

The complete results will be published in the *Journal of Agricultural Research*.

THE work was carried out as a part of a Bankhead-Jones research project on papaya pollen germination and storage; rate of pollen tube growth and duration of pistil receptivity. The present report deals only with pollen germination and storage, a method for the handling of a solid germination medium for pollen germination tests in Van Tieghem cells has been worked out; papaya pollen germinated successfully in agar-sucrose media over a fairly wide range of sucrose concentrations (1 to 8 per cent) and equally well at $\frac{1}{2}$ to $\frac{3}{4}$ per cent agar, and the standard medium used in the experiments was $\frac{3}{4}$ per cent agar and 4 per cent sucrose. The best pollen storage conditions as established by these experiments, which included four temperature (1.1 degrees C; 10 degrees C; 22.2 degrees C, and 27.8 degrees C) and six humidity conditions (ranging from near 0 per cent to 96 per cent), are 1.1 degrees C (34 degrees F) and approximately 10 per cent relative humidity; under the best conditions papaya pollen has now been stored for more than five months with still a fairly high percentage of germination, 80 per cent for *C. quercifolia*; 45 per cent for *C. papaya* hort. var. Miami.

Self- and Cross-Pollination in the McIntosh Apple and Some of Its Hybrids

By L. P. LATIMER, *University of New Hampshire, Durham, N. H.*

BEFORE planting new varieties of apples, growers usually seek information concerning their pollination requirements. For that reason, pollination tests were started at the New Hampshire Experiment Station in 1934 to determine the interrelations between McIntosh and some of its more promising seedlings, namely Cortland, Melba, Early McIntosh, Milton, and Macoun. Self- and cross-pollination tests have been conducted with these varieties. In addition, each variety except Early McIntosh has been pollinized by Starking as a standard of comparison. Early McIntosh is the only one of these that has not been used as a female parent; and no test has been made of Macoun as a pollinizer for McIntosh.

The trees used in the experiment were enclosed in cheesecloth cages during the blossoming period. The technique used in hand pollination has been described by the writer in a previous publication (1). MacDaniels (2) and Murneek (3) have discussed the advantages of this method. Data of averages for 3 years are presented in Fig. 1.

The uniformly high percentage of blossoming spurs setting fruit in all varieties when Starking was the pollen parent (at least 60 per cent of the blossoming spurs) is strongly correlated with a high seed-count (average about eight seeds), and few empty seed cavities. Consequently, only about 10 per cent of these fruits were lopsided or misshapen. As pollen parents, Cortland, Milton, Melba, McIntosh, and Macoun gave results similar to Starking.

With self-pollination, only 2 per cent of the blossoming spurs of McIntosh set fruit, with Cortland 3 per cent, and only 1 per cent in the case of Milton and Macoun. The exception was Melba, where 22 per cent of the blossoming spurs set fruit with self-pollination. When Cortland was pollinated by Early McIntosh, the results were nearly the same as when Cortland was self-pollinated, indicating in this case an incompatible cross.

When McIntosh or its hybrid seedlings were self-pollinated (Fig. 1), the presence of only one or two seeds per fruit resulted in a high percentage of lopsided specimens. This was also the case when Cortland was pollinated by Early McIntosh.

When self-pollinated, the fruit of Melba had fewer seeds than the other hybrids, or McIntosh. In most instances, the Melba fruits contained no seeds at all. The dried up ovules were detectable as black specks in the carpel. These fruits were normal in shape, lopsidedness occurring only when one or two seeds were developed. However, the seedless fruits were about 20 per cent smaller than those containing seeds. In the selfed fruits of the varieties McIntosh, Cortland, Milton, and Macoun, there was always at least one seed present which, however, was abnormal in shape and size, and usually not viable. No significant differences in weight were found between cross- and self-pollinated fruits of McIntosh, Cortland, Milton, and Macoun, on individual trees, unless the crop was heavy.

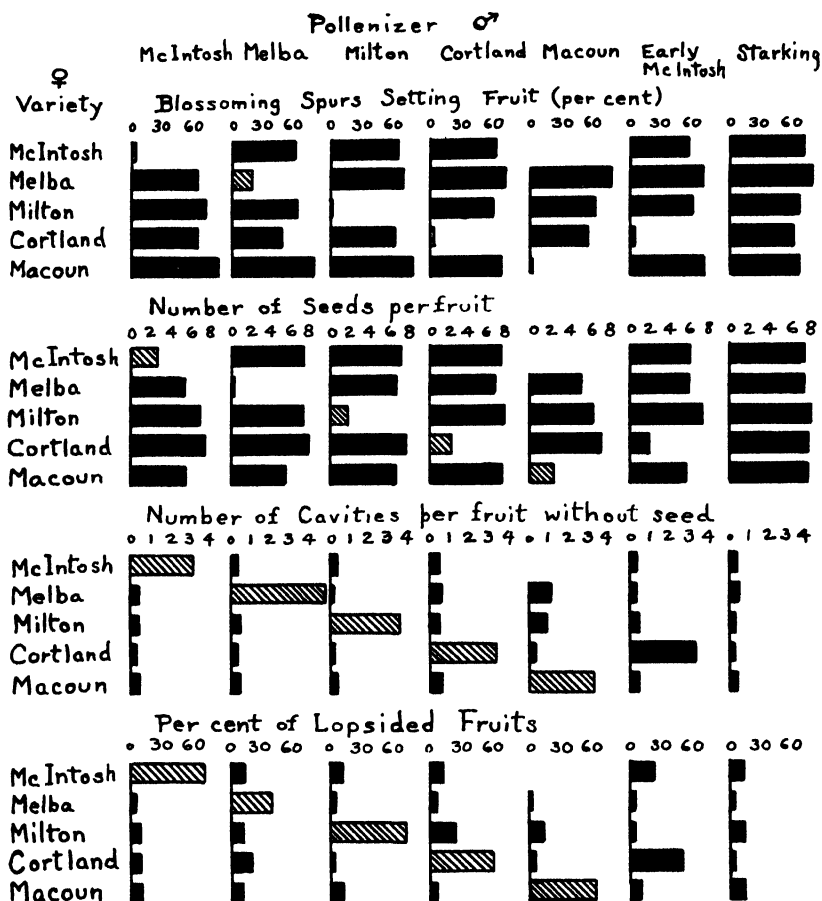


FIG. 1. Relation between fruit setting, seed count, and lopsidedness in self- and cross-pollinated McIntosh and some of its seedlings.

Table I shows that Melba and Macoun set a significantly larger per cent of fruit than McIntosh, Cortland, or Milton regardless of the kind of pollen used.

Considering Starking and all the McIntosh type varieties mentioned previously, no significant advantage can be attributed to any one over another as a pollinizer for McIntosh or its seedlings except that Early McIntosh does not pollinize Cortland satisfactorily. Therefore, for commercial purposes, the commercial value of the variety should guide the grower in his choice of pollinizers, realizing that none of them will be profitable without provision being made for cross-pollination. Although Melba may produce a partial crop with self-pollination, it must be remembered that the fruit will be larger when cross-pollination is provided.

TABLE I—COMPARATIVE EFFECTIVENESS OF POLLEN VARIETIES ON MCINTOSH AND SOME OF ITS SEEDLINGS, 1934-35. PER CENT OF BLOSSOMING SPURS SETTING AND MATURING FRUIT

Pollen Variety	Variety Pollinized					
	McIntosh	Melba	Milton	Cortland	Macoun	Mean (σ^7)
McIntosh	2	67	75	68	87	74.3
Melba	64	22	67	52	83	66.5
Milton	69	73	1	66	82	72.3
Cortland	66	76	63	3	72	69.3
Macoun	—	82	67	59	1	69.3
Early McIntosh .	60	74	62	5	75	67.8
Starking	76	83	71	65	70	73.0
Mean (♀)	64.8	74.4	66.8	61.3	79.8	

Self-pollination results not included in average

Early McIntosh-Cortland cross results not included in average.

Differences between means for (σ^7) are not significant. F (Snedecor) is 0.45 whereas F in this case to be highly significant should be 7.31.

For (♀), F=8.15; necessary to be highly significant 4.58. Standard error for difference between two means is here 4.0

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The Effect of Reducing the Number of Functioning Stigmas on Fruit-Setting and Characteristics of the McIntosh Apple

By L. P. LATIMER, *University of New Hampshire, Durham, N. H.*

APPLE growers are sometimes mystified to see fruit develop and mature from blossoms which had been severely injured by spring frost. In 1934, a severe freeze at blossom time caused extensive injury to apple flowers in many localities, resulting generally in the browning of both stigmas and ovary. The anthers of these flowers also showed varying degrees of injury. However, there was an occasional blossom in which one or two stigmas remained green and apparently uninjured. On certain trees it was impossible to find any undamaged flowers, yet about two boxes of mature apples of fairly good form and containing three to 10 seeds were harvested from each of these trees. Results obtained by the writer and by others in pollinating partially destigmatized blossoms, indicate that the few uninjured stigmas probably permitted sufficient pollination to cause a set of fruit on five to ten per cent of the blossoming spurs.

Sax (2) removed two stigmas each from flowers of Ben Davis and pollinated the remaining three with McIntosh pollen. Many misshapen apples were formed and 73 per cent of the fruits contained one or more empty locules. Beaumont (1) removed varying numbers of stigmas from flowers of Early Strawberry Crab and Perkins apples, leaving them to open pollination. Where only one stigma was allowed to remain a reduced set of fruit resulted in Early Strawberry Crab. In both varieties seed developed in fewer locules than when flowers retained all five stigmas. Furthermore, 25 per cent of the Early Strawberry Crab and 57 per cent of the Perkins fruits resulting from single pistil pollination had more locules filled with seed than there were functioning styles, which indicated that the full coterie of stigmas and styles was not necessary in order for fertilization to take place in all the carpels. The more striking result with Perkins was attributed to the possibility that the open core of this variety permitted pollen tubes to pass readily from one locule to another. There was no set of fruit in either variety when all the stigmas were removed.

In 1929 just as the petals were unfolding and before self-pollination could have taken place some of the stigmas were removed from certain flowers of a moderately vigorous McIntosh tree located in a sod or chard. Red Astrachan pollen was then applied to the remaining four stigmas in each of 33 flowers, three in each of 30, two in each of 35, one in each of 37, and to the stubs left when all the stigmas were removed in 35 other flowers. To serve as a standard of comparison, Red Astrachan pollen was applied to all five stigmas of 54 blossoms. In this case seeds were present in all the locules of 96 per cent of the resultant fruits, and in all but one locule of each fruit of the remaining 4 per cent (Table I). With only one stigma cross pollinated, 12 per cent of the fruits contained one empty locule, 38 per cent two, 25 per cent

TABLE I—EFFECT OF PISTIL REMOVAL ON WEIGHT, SEED, NUMBER OF EMPTY LOCULES AND SHAPE OF FRUIT DEVELOPING FROM CROSS POLLINATION IN MCINTOSH*

Year	Soil Management	Number of Stigmas Pollinated	Number of Apples	Average Weight	Average Number Seeds	Average Number Empty Locules	Fruits Lopsided (Per Cent)
1929	Sod	1	9	62	2.3	2.4	38
		2	4	64	5.8	0.8	50
		3	8	63	5.1	0.9	63
		4	17	60	4.8	0.8	35
		5	27	78	8.4	0.04	7
1930	Cultivation	1	16	139	6.3	0.6	19
		2	19	115	8.2	0.2	11
		3	12	121	8.4	0.0	17
		4	0	—	—	—	—
		5	127	154	10.0	0.06	9
1933	Cultivation	1	50	157	5.4	1.3	34
		2	15	181	7.3	0.6	27
		3	14	178	7.1	0.6	14
		4	15	169	6.5	1.0	7
		5	59	140	8.8	0.1	3

*Red Astrachan pollen was used in 1929 but Delicious pollen in 1930 and 1933.

three, and the remaining 25 per cent four empty locules. No fruit set where completely destigmatized flowers received Red Astrachan pollen.

Subsequently (1930 to 1934 inclusive) McIntosh trees under cultivation were used for the experiment. Here the partially destigmatized flowers received Delicious pollen. The resulting fruits contained more seeds and fewer empty locules than those observed in 1929. There was no significant difference between the per cent of blossoming spurs setting fruit whether one or five pistils received Delicious pollen (74.3

TABLE II—CLASSIFICATION OF RESULTS WITH CROSS POLLINATION OF FIVE AND ONE STIGMAS EACH PER FLOWER AND WITH SELF POLLINATION OF MCINTOSH 1930-1934

Type of Pollination	Cross	Cross	Self
Number of Stigmas Pollinated	5	1	5
Per cent of fruits containing:			
No seed	0.0	0.0	0.0
Seed in one locule only	0.0	0.6±0.55*	58.8±10.54*
Seed in two locules only	0.6±0.34*	4.0±1.07	21.8± 8.73
Seed in three locules only	3.0±0.95	18.1±3.34	7.4± 3.34
Seed in four locules only	10.3±4.71	25.3±4.31	12.0± 5.01
Seed in every locule	86.1±5.47	52.0±5.93	0.0± 0.00
Average number of seeds per fruit . . .	9.4±0.46	6.7±0.42	2.0± 0.26
Average number of empty locules per fruit	0.1±0.03	0.8±0.10	3.3± 0.18
Average per cent of fruits lopsided . . .	9.0±0.98	23.0±2.50	73.0± 6.58
Average per cent of blossoming spurs setting fruit	68.7±2.61	74.3±1.94	3.2± 0.98

*Standard error.

and 68.7 per cent respectively). Yet self-pollination resulted in fruit on only 3 per cent of the blossoming spurs.

If the number of functioning styles was reduced to one in each flower, there was a slight increase in the number of seedless carpels in the resultant fruits (Table II and Fig. 1). With a reduction in the number of functioning pistils to one in each flower, there was a decrease in the number of seeds per fruit and an increase in the number of seedless carpels and lopsided fruits (Table II).

Data obtained in 1929, 1930, and 1933 indicate that when two, three and four stigmas, respectively, per flower, were cross pollinated, the numbers of seeds, and empty cavities and per cent of fruits that were

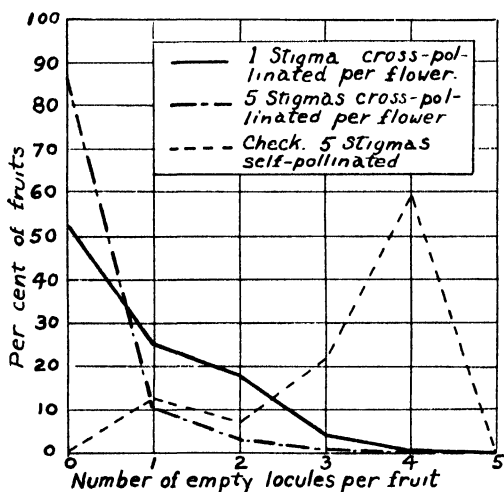


FIG. 1. Effect of pollination and number of functioning stigmas on seedlessness in the Carpels of McIntosh.

lopsided were substantially the same in the three cases. Yet these values were intermediate between those obtained for one and five pistil pollination (Table I). As in Beaumont's experiment, no fruit set when pollen was applied only to the ends of the stubs left after destigmatization.

DISCUSSION

Contrary to the results obtained by Beaumont (1) with the Early Strawberry Crab apple, McIntosh showed no significant differences in percentage of blossoms setting fruit when different numbers of pistils were pollinated. The data for McIntosh, however, is in agreement with the conclusions of Beaumont that a considerable amount of fruit may develop if only one functional pistil is present and that this condition is superior in many respects to self pollination. Obviously (Table II) a close relationship exists between the number of empty locules per fruit and the per cent of fruits that are lopsided. In fact, a correlation coefficient of 0.942 between the number of empty locules and per cent of fruit lopsided was found to exist, a value which does not deviate far from a perfect correlation. In addition there was found to be a negative correlation of 0.878 between seed content and per cent of misshapen fruit.

That the increase in seed number found as we pass from self-pollination to one pistil and then to five pistil cross-pollination is due to more effective pollination there can be little doubt, since these observations were made on the same trees. The same must also be true for the reduc-

tion in number of empty locules, which is so closely correlated with the amount of lopsidedness.

With favorable conditions for pollination, it is possible for a normal set of fruit in McIntosh to take place, although there may be less than five functioning styles per flower. This doubtless explains the set of fruit sometimes obtained when frost damages the blossoms just as they are opening.

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Polyploidy in Native Species of *Malus*¹

By F. B. LINCOLN and L. P. McCANN, *University of Maryland, College Park, Md.*

A FAMILIAR acquaintance with the taxonomy, variation, distribution, and responses of the native species of *Malus*, and their cytogenetics is of much importance to anyone interested in the biology of the apple. When this present investigation was started it was assumed that there was a probable possibility that the members of the taxonomic section *chloromeles* were geographic species showing ecological adaptation, variations, and hybridity. Furthermore it was conjectured that the members were tetraploids and might exhibit apogamy.

Seedlings were obtained of seeds collected from identified specimens growing in the wild and in various arboretums. In all cases there was the possibility of cross pollination, but the seedlings grown showed remarkable constancy to type in respect to visible characteristics, with the exception of one lot of *Malus angustifolia* and one group of *M. coronaria* seedlings.

The root tips were killed with Nawashin solution and the sections for observation were prepared by the usual conventional methods.

Chromosome counts were made for the species of this section as listed by Van Eseltine, and are tentatively given below. Certain chromosome numbers as determined by Nebel are also given.

SECTION CHLOROMELES, REHDER

	Lincoln	Nebel
<i>Malus platycarpa</i>	68	—
<i>Malus ioensis</i>	34	34
<i>Malus angustifolia</i>	34	—
<i>Malus glaucescens</i>	68	68
<i>Malus glabrata</i>	68	—
<i>Malus lancifolia</i>	51	—
<i>Malus coronaria</i>	68	68
<i>Malus bracteata</i>	51	—

To give certainty to these chromosome counts, other specimens of these species from various locations, and some of their named varieties and hybrids are being grown for cytological observations. The constancy of these seedlings to a type will be noted, and when it is possible, pollination studies will be made between these species and between them and *Malus domestica*.

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¹Acknowledgment and sincere gratitude is due for the real assistance of others in obtaining this material and the use of facilities in conducting this study.

The Use of Growth Substances for Inducing Root-formation in Cuttings

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ABSTRACT

APPROXIMATELY 100 varieties of cuttings were treated with water solutions of indoleacetic, indolebutyric, or *a*-naphthaleneacetic acids for periods of a few hours to 48 hours previous to being planted in the rooting medium (half sand and half peat moss by volume). Treatment consisted of placing the basal ends of the cuttings in a tap water solution of the growth substance for a designated number of hours. In most cases the treatment induced more roots in a shorter period of time than on control cuttings placed in tap water, regardless of whether or not the variety was normally difficult to root.

Effective concentrations ranged from 1:1,000,000 to 1:2,500 depending upon the duration of treatment, variety of cutting, and the kind of growth substance used. Pure *a*-naphthaleneacetic acid was slightly more effective than indolebutyric acid and both of these substances were much more effective than indoleacetic acid. Comparative tests on the rose, which is one of the most sensitive plants tested, showed indolebutyric acid to be from 10 to 20 times more effective than indoleacetic acid.

The effectiveness of the treatment was primarily a function of concentration and not of the total amount of solution absorbed. The average number of roots per treated cutting was also a function of concentration—the higher concentrations in some cases inducing the formation of from 50 to 100 or more roots on a single cutting. Considering the wide range of effective concentrations, according to the variety tested, no single treatment can be safely recommended for all varieties. The optimum treatment for rose cuttings was not at all effective on cuttings of boxwood, Japanese maple, and most evergreens. Conversely, the use of treatments which were optimum for the last named varieties caused marked injury or killed the stems of rose cuttings. High concentrations of growth substance (generally higher than can safely be recommended for practical use) induced roots to grow from tissue, not only at the base of the cutting, but also from tissue up the stem for a distance of several inches and to the tip. These results show that indoleacetic acid as well as indolebutyric and *a*-naphthaleneacetic acids move readily upward in stems of cuttings and hence are opposed to the theory that heteroauxin (indoleacetic acid) and other growth substances exhibit only a (downward) polar movement. With respect to the non-polar movement of growth substances, these results confirm those previously published concerning the treatment of cuttings and potted plants.

Such varieties as *Acer palmatum*, Azalea, blueberry, Clematis, Cornus, Corylus, *Daphne cneorum*, Ilex, Magnolia, Malus (Pyrus), Prunus, rose and Ulmus were successfully rooted by the solution method of treatment. It is believed that the production of much larger and more efficient root systems on cuttings of many varieties of plants will

offer new possibilities in the establishment and growth of plants on their own roots.

Most of these tests apply to cuttings with leaves, particularly softwood or greenwood cuttings. In a few cases (peach, poplar, privet, and Hibiscus) dormant leafless hardwood cuttings responded the same as the greenwood cuttings. In contrast, the dormant cuttings of the Concord grape required a much stronger treatment than the softwood cuttings taken during July.

A more detailed report of these results will appear in an early issue of the Contributions from Boyce-Thompson Institute.

The Influence of Different Pollens on the Development of the Pistache Nut

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RESULTS obtained at Sacaton, Arizona, during 1 year (1933) indicate that the fruit of the pistache is influenced by the kind of pollen used. The three characters affected by the different pollens were maturation and, less definitely, dehiscence and length of pericarp. These characters are apparent in the mother tissue as distinguished from the zygotic or hybrid parts of the seed, and thus any variation in them effected by pollen might be considered as metaxenia, as defined by Swingle (1). But if the differences found were due to delayed fertilization, then the explanation might be physiological instead of metaxenic. Unfavorable seasonal conditions have prevented repetition of these experiments in subsequent years.

The experiment involves three species of the genus *Pistacia*. *Pistacia vera* was utilized as the pistillate or seed parent, and *P. atlantica*, *P. chinensis* and a hybrid of unknown ancestry as the staminate or pollen parents. The male trees were close together in the same row, but their flowering periods differed sufficiently for uncontaminated pollen to be obtained without recourse to bagging.

The data presented in this paper are based on observations made on pistache nuts produced on three adjacent trees of the Trabonella variety and a nearby tree of Red Aleppo. The latter is appreciably earlier both in flowering and fruiting, and the maturation data obtained from it are treated separately. The three Trabonella trees are of identical age and approximately the same size and the data obtained from them are treated as one array.

All of the pistillate flower clusters were bagged on the same date, before any male tree nearer than 1 mile had flowered. Within each variety the selected clusters were in about the same stage of development. Seventeen clusters were bagged on each tree, five for each of the three different pollens and two as unpollinated controls. Three additional control bags were placed on other trees, making a total of 11 clusters so treated. A few of the manila paper bags were equipped with cellophane windows, so that development of the flowers could be observed without removal of the bags and the consequent risk of contamination by accidental pollination.

The pollinations were made on March 29. One operator punctured the bag, sealing the rent with gummed paper immediately after the second operator had applied the pollen. The pollen was introduced in great abundance.

The control bags were punctured and sealed as in the others, but no pollen was applied. The 11 control clusters produced 252 nuts, all of which were infertile, containing abortive seeds.

In the fertilized nuts a definite change in appearance of the pericarp from glossy, translucent and green, to dull, opaque, and white, provided a convenient criterion of maturity.

TABLE I.—PERCENTAGE OF RIPE NUTS ON DIFFERENT DATES OF OBSERVATION IN FRUIT CLUSTERS POLLINATED WITH THREE DIFFERENT KINDS OF POLLEN

Date	Percentage of Ripe Nuts			Percentage Difference				
	Hybrid Pollen	Atlantica Pollen	Chinensis Pollen	Hybrid—Atlantica	D/E*	Hybrid—Chinensis	D/E	Atlantica—Chinensis
<i>Nuts Borne on Three Trabonella Trees</i>								
Aug. 28.	80.8±2.50†	53.1±6.64	9.9±2.92	27.7±7.10	3.9	70.9±3.84	18.5	43.2±7.25
Sept. 6	86.9±2.81	71.6±4.25	13.0±3.23	15.3±5.10	3.0	73.9±4.28	17.3	58.6±5.34
Sept. 13	91.8±1.32	85.4±2.41	28.4±5.97	6.4±2.75	2.3	63.4±6.11	10.4	57.0±6.44
Sept. 20	95.3±1.63	93.0±1.61	58.6±7.41	2.3±2.29	1.0	36.7±7.59	4.8	34.4±7.58
Sept. 27	95.6±1.61	95.2±1.25	66.5±7.44	.4±2.03	.2	29.1±7.61	3.8	28.7±7.54
Oct. 16.	100.0	98.6±6.82	82.5±6.87	1.4±6.82	.2	17.5±6.87	2.5	16.1±9.68
<i>Nuts Borne on a Single Red Aleppo Tree</i>								
Aug. 14.	72.8±2.15†	56.7±3.28	15.3±2.81	16.1±3.92	4.1	57.5±3.39	17.0	41.4±4.32
Aug. 18.	88.2±1.56	83.7±2.41	25.0±3.44	4.5±2.87	1.6	63.2±3.78	16.7	58.7±4.20
Aug. 22.	94.5±1.19	95.2±1.41	38.9±3.86	-7±1.85	.4	55.6±4.04	13.8	56.3±4.11
Aug. 24.	96.9±.84	95.2±1.41	41.7±3.92	1.7±1.64	1.0	55.2±3.88	14.2	53.5±4.17
Aug. 31.	98.0±.68	97.1±1.11	43.1±3.94	9±1.30	.7	54.9±4.00	13.7	54.0±4.09
Sept. 6.	98.0±.68	97.1±1.11	50.0±3.98	.9±1.30	.7	48.0±3.91	12.3	47.1±4.13
Sept. 13	99.5±.35	99.0±.66	65.3±3.78	.5±0.75	.7	34.2±3.79	9.0	33.7±3.84
Sept. 20	100.0	100.0	75.0±3.44	-5±0.35	1.4	24.5±3.31	7.4	25.0±3.44
Sept. 27	100.0	100.0	79.2±3.23	—	—	20.8±3.23	6.4	20.8±3.23
Oct. 16.	100.0	100.0	83.3±2.97	—	—	16.7±2.97	5.6	16.7±2.97

*Difference divided by probable error of the difference

$$\dagger P.E. = \frac{.6745s}{\sqrt{n-1}}$$

$$\dagger P.E. \% = \frac{.6745 \sqrt{\% (100 - \%)}}{\sqrt{n}}$$

The effect of pollen on the time of ripening is shown in Table I, in which the mean percentage of ripe nuts is given for each pollen on the successive dates of observation, and also the difference in percentage of ripe nuts for all possible comparisons of pollens. For convenience in analyzing the data probable errors are given, and in the pollen comparisons the difference divided by its probable error (D/E) is given as an aid in estimating the significance of the difference.

In both varieties, the percentage of ripe nuts on all dates of observation is lower for *chinensis* pollen. At the time of the first observation, on August 28, only 9.9 per cent of the Trabonella nuts pollinated with *chinensis* pollen had matured, whereas the percentage was 80.8 for the pollen from the unknown hybrid. In the earlier Red Aleppo variety, the percentage of ripe nuts in the first observation, August 14, was 72.8 and 15.3, for the hybrid and *chinensis* pollens, respectively.

The delay in ripening caused by *atlantica* pollen, as compared with the pollen from the hybrid, is not so pronounced, although in the first two observations the difference is appreciable.

A certain percentage of the nuts, varying with the variety and probably other factors, is self-splitting. The shell dehisces along the longitudinal suture, partially exposing the kernel. Production of a high percentage of self-splitting nuts is desirable from a commercial standpoint. The evidence submitted in Table II indicates that *atlantica* pollen increased the percentage of self-splitting in the Trabonella variety. Where this kind of pollen was used, the percentage self-split is 88.2, 15.7 greater than the percentage obtained with the pollen from the hybrid and 13.4 greater than with *chinensis* pollen.

TABLE II---APPARENT EFFECT OF POLLEN ON DEHISCENCE IN TRABONELLA VARIETY OF PISTACHE

Kind of Pollen	Number of Nuts	Percentage Dehiscent	D/E
<i>Atlantica</i>	187	88.2±1.59	4.6
Hybrid	102	72.5±2.98	
Difference		15.7±3.38	
<i>Atlantica</i>	187	88.2±1.59	4.0
<i>Chinensis</i>	131	74.8±2.96	
Difference		13.4±3.36	
<i>Chinensis</i>	131	74.8±2.96	.5
Hybrid	102	72.5±2.98	
Difference		2.3±4.08	

The mean length of the entire fruit differed for each kind of pollen. The greatest difference is only 3.9 per cent of the length of the fruits pollinated with hybrid pollen, but this small difference is 6.6 times its probable error. The data pertaining to this character are presented in Table III.

TABLE III—APPARENT EFFECT OF POLLEN ON LENGTH OF PERICARP IN TRABONELLA VARIETY OF PISTACHE

Kind of Pollen	Number of Nuts	Length of Entire Nut (Mm)	D/E	Length of Hulled Nut (Mm)	D/E
Hybrid	101	26.89±.12	6.6	20.82±.08	.5
<i>Chinensis</i>	131	25.84±.10		20.76±.07	
Difference		1.05±.16		.06±.11	
Hybrid	101	26.89±.12	3.7	20.82±.08	1.4
<i>Atlantica</i>	186	26.37±.07		20.69±.05	
Difference		.52±.14		.13±.09	
<i>Atlantica</i>	186	26.37±.07	4.4	20.69±.05	.8
<i>Chinensis</i>	131	25.84±.10		20.76±.07	
Difference		.53±.12		.07±.09	

Measurements made on the same lot of nuts show that the length of the hulled nuts did not vary significantly with the different pollens, the greatest difference being only 1.4 times its probable error. The variation in length of the fruit effected by the different pollens was confined to the pericarp.

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Low Temperature Injury to Orchards in Pennsylvania and Adjoining States in the Fall and Winter of 1935-36¹

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EXTRAORDINARY weather conditions always arouse anxieties in the minds of fruit growers. Both the winter of 1933-34 and that of 1934-35 had caused injury to fruit trees in Pennsylvania. The unusual weather in the fall of 1935 and the early days of 1936 caused many to inquire anxiously, "What has the cold done to the orchards this winter?" To attempt to find an answer to this question the Department of Horticulture of the Pennsylvania State College, during the summer of 1936, undertook a survey of the orchard areas of Pennsylvania and adjoining states.²

In each area visited, the extent and nature of any winter injury to fruit trees were determined; then the factors of variety, age, vigor, soil, exposure, cultural methods, and weather were studied to find which had contributed to this injury.

Various members of the Horticultural Departments of the New York, Ohio, and Maryland Stations gave much help in reporting conditions in their states and in suggesting orchards to visit. The assistance given by I. P. Lewis of the Ohio Station was of particular value.

WEATHER CONDITIONS

The period from October 5 to 9, 1935, was unusually cold throughout Pennsylvania. At State College, the official minimum temperatures on October 7, 8, and 9 were 25, 27, and 29 degrees F with corresponding temperatures at the College orchard of 19, 22, and 22 degrees F. Apples hanging on the trees were frozen to the core each morning. In the fruit regions to the east and south, temperatures were not so low as in the College orchard but were well below the frost point.

Immediately following this cold period, apple leaves showed very few external signs of frost injury but a few days after there was an unusually heavy drop of apple leaves throughout the state. Those leaves which did not drop at this time held on much later than usual. Apparently the normal formation of the abscission layer was upset by the freeze. In the late fall there was less than the normal amount of sunshine. The immediate effect of the cold period on the apple fruit was to cause the stem to separate from the spur much more readily and in 10 days to 2 weeks there was a very heavy drop throughout the state. The frosted fruit softened rapidly; fruit picked even before the heavy drop had to be disposed of before Christmas.

Unfortunately, few observations were made immediately at State College to determine the amount of cambial and sap wood injury caused by this cold period. In some 15 year old Bosc and Sheldon pears it was

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²The cooperation of the American Cyanamid Company in supplying the traveling expenses of the survey is gratefully acknowledged.

noted that considerable areas of trunk cambium turned dark in a few days but there was no separation of the bark from the wood. No such darkening of the cambium was observed with apple trees.

January, 1936, will long be remembered by Pennsylvanians. The first half of the month was mild, with little snow cover in the eastern half of the state. On the 19th there was a sudden temperature drop accompanied by a blizzard. The weather moderated rapidly on the 20th and 21st. The morning of January 22 was warm and bright and pruning crews in the western part of the state were working in their shirt sleeves at 10 o'clock; by 5 o'clock a blizzard was blocking rapidly all roads and the thermometer had dropped to 10 or 15 degrees below zero, —a total drop of from 40 to more than 50 degrees. This sudden drop in temperature with snow and high winds was general throughout the state; but, as the storm moved from southwest to northeast, the drop in temperature was progressively later in the day from west to east. At State College the temperature drop began early in the afternoon and did not reach its lowest point until late in the evening. In the main fruit regions of the state south and east of the Alleghenies, it was a late afternoon and evening storm. Because of this change in the time of onset, the rapidity and intensity of the drop decreased to the east of the higher areas of the Allegheny Plateau. Total temperature drops in parts of southeastern Pennsylvania were as little as 30 degrees. There was also a lessening of the intensity of the cold beginning about halfway between Pittsburgh and Lake Erie and extending northward.

After this sudden drop the weather continued abnormally cold until nearly the end of February. At State College there were 13 days of sub-zero weather up to the 20th of February, when it was 8 degrees below zero. The blizzard of January 19 gave 15 inches of snow at State College and a heavier cover to the east. The snow cover was about 2 feet deep until March.

THE SURVEY

The survey was started late in June. By that time it was apparent that there had been such heavy branch and bud killing on peach trees throughout most of the state that this fruit was probably not a good guide to use in determining causes of winter injury. No specific records were made of peach tree injury except in a few cases where there were considerable differences in injury among nearby orchards.

Likewise, no detailed notes were made of either sweet or sour cherry orchards, but the sweet cherries along the roadsides were found to be a valuable guide in each new region. Where these trees—chiefly Mazzard seedlings—showed any considerable amount of branch killing, some apple tree injury of a less severe degree would be found. When any of the Mazzards were killed, some apple trees would be found with severe trunk or branch injuries.

Considerable care had to be used in interpreting fruit tree injuries, particularly with sweet cherries. Unusually low temperatures in both the winters of 1933–34 and 1934–35 had injured many fruit trees in all fruit regions of the state. Much of this injury consisted of dead areas of trunk cambium and sapwood covered by unbroken bark. Few growers saw these until this dead bark began to come off in 1936; then they attributed the injury to the winter of 1935–36. In Baldwin and

similar varieties, where winter injury causes the death of the sapwood of lower branches, again much of the early injury escaped notice until considerably later.

It is highly probable that the full extent of injury from these past three winters has not yet become apparent. In the orchards at State College, no injury from the winter of 1935-36 was observed while this survey was in progress and it was almost by chance that dead areas of trunk bark were discovered in late September. Then a thorough examination showed a large proportion of the trees with injuries ranging from a few spots the size of a silver dollar to areas covering a third of the circumference of the trunk; some crotch injury was found also. Throughout the survey it was necessary to tap the trunks lightly with a knife handle to detect injury on many of the trees, although after a very hot period in July a large number of injured trees could be located by a yellowing of the foliage.

In any intensive study of winter injury to fruit trees a knowledge of the location and degree of sapwood injury is highly desirable; yet in this survey no particular attempt was made to study the sapwood as it was assumed that many growers would be reluctant to permit the amount of cutting necessary to secure a reliable picture of the sapwood condition. It was thought that the condition of the bark would be a sufficient guide to the degree of injury. This was not so true with Baldwin and Rhode Island Greening; the lower branches of these varieties might be killed, while the trunk bark and even the crotches showed no external signs of injury.

AREA OF SEVEREST INJURY

It was soon evident that for the purposes of this survey, the state could be divided into three areas: a region in which there had been no damage from the winter of 1935-36; a region of severe injury where some entire orchards had been killed and where many orchards had as high as 50 per cent of the trees injured; and a transition, or marginal, zone where occasional orchards suffered injury but where the total damage was not excessive.

The greatest injury to orchards was in the western half of the state in an elliptical area centering roughly around Pittsburgh and extending approximately 50 miles north and 25 miles south of that city, and 75 miles east with a somewhat indefinite western border in Ohio. The Pittsburgh area likewise presented the greatest contrasts. It was not uncommon to find in one orchard nearly all of the apple trees, regardless of variety, showing considerable damage, while in another orchard, only a few miles from the first, apple trees were without any visible signs of injury.

The initial factor predisposing the trees to injury in the Pittsburgh district were the heavy freezes of October 7, 8, and 9. Orchards in which these occurred were peculiarly liable to show severe damage and orchards on favorable sites where these freezes were not so severe exhibited little or no harm.

Soil freezing in 1935-36 was not a factor in this area, since the ground was heavily blanketed with snow.

The type of injury exhibited by apple varieties other than Baldwin, Rhode Island Greening, and Wagener, consisted of a complete or partial loosening of the entire bark cylinder of the trunk from a point near the ground line up to or even including the bases of the scaffold limbs. McIntosh, which is usually considered a hardy variety, frequently showed this type of injury. In many instances, the bark cylinder split wide open by spring so that the grower was able early to see some of the injury. In other cases, while the bark was killed and loosened partially, it did not crack open in the spring and, to all appearances at that time, nothing seemed to be wrong with the tree.

Baldwin was the variety most often injured, as in 1933-34, even in orchards where no other varieties were affected. When individual trees had not borne a crop in 1935, the degree of injury was either reduced or apparently eliminated. Wagener and Rhode Island Greening also were injured severely. Trees of these three varieties showed limb and top killing, not the loose trunk bark type found in the other varieties.

Next to Baldwin, the chief sufferers were Stayman Winesap, Red Delicious, Rome, and McIntosh. Wealthy was not particularly resistant to bark loosening.

From the survey in the Pittsburgh area, it became apparent that old standards of hardiness to freezing were of little value when the killing was chargeable to a lack of maturity, instead of to the minimum temperatures attained. Under the conditions of 1935-36, there were no hardy apple varieties in this area of excessive killing.

Apple trees injured at the collar or higher up on the trunk in 1933-34, and which showed in consequence areas of dead bark, were apparently immune to damage in 1935-36.

Apple bud injury was fairly conspicuous in this area, although several orchards losing the greatest proportions of their trees because of loose trunk bark had what the orchardists claimed was a nearly normal bloom. Abnormal apple blossoms also were observed by many growers.

Apple trees of both extremes of vigor were harmed, while those more nearly midway within these limits were considerably more resistant, all other factors being equal. It was evident that wet feet, previous drouth damage, a thin soil, severe spray injury, defoliation by scab, unchecked San Jose scale attacks, and the like had all played their part in increasing the amount of injury to trees of low vigor.

One large orchard injured most seriously was on a thin, fairly light soil of low fertility on which the trees had not recovered fully from the drouths of 1928 and 1930. In this instance, fertilizer applications were rather light, spray injury in 1935 was severe, the 1935 crop was heavy, and abundant autumn rainfall followed by the October freezes prevented the attainment of a proper degree of tree maturity. About 100 acres of this orchard were completely wiped out.

On the other hand, heavy applications of animal manures or commercial fertilizers likewise resulted in severe losses, especially if accompanied by late cultivation. One orchardist applied in April, 1935, 22 pounds of ammonium sulfate per tree, disced the sod before bloom, then followed this with 2 pounds more sulfate per tree late in June. This liberality cost the owner a third of his fine, 22-year-old apple

trees, chiefly Stayman Winesap. Another grower applied in the spring 8 pounds of sulfate of ammonia per tree, then cultivated frequently until late August, in the meantime fertilizing his trees very heavily with the manure from his large dairy herd. These practices have cost him dearly, for in addition to winter injury, fire blight in the summer of 1936 was raging on what trees were left relatively uninjured by freezing.

An attempt was made to correlate the usual commercial forms of nitrogen-carrying fertilizers with the degree of injury but no conclusion could be drawn from the evidence. Most of the growers in the Pittsburgh area had used calcium cyanamide in 1935, chiefly because of its

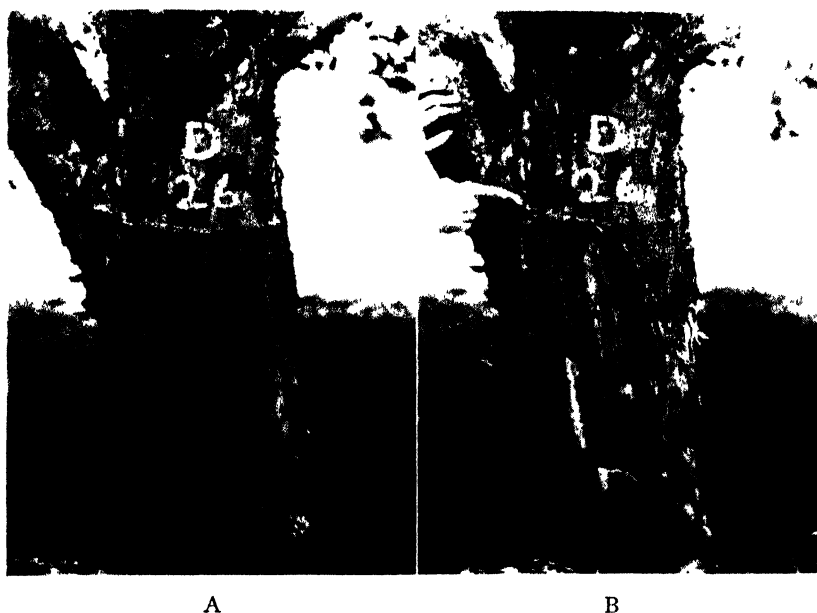


FIG. 1. York Imperial on Northern Spy intermediate stock. October, 1936. White line indicates York-Spy graft union. A, Before removing dead bark. Cracks in Spy bark first became visible late in September, 1936. B, After removing dead bark. This area is on the Northern Spy trunk only. Injury stops abruptly at York union.

considerably lower price per unit of nitrogen as compared with other forms of nitrogen. When comparisons could be made with other forms of nitrogen, there was no evidence that cyanamid had either increased or decreased the degree of injury.

Most growers with severe tree injury had observed a heavy premature drop of leaves in 1935 following the October freezes, although some with considerable losses stated that the leaves had persisted abnormally late until January and February.

Trees picked previous to the freezes tended to show less injury, although the distinction was not always clean cut.

There was some indication in this area that autumn pruning had been a factor in promoting trouble, although too few growers had been able

to do any pruning before the severe January weather to make this observation as well substantiated as might be desired.

Intermediate stocks utilized in several orchards with double-worked trees were a source of weakness. Spy was a failure as an intermediate stock for York and Stayman Winesap in the 28-year-old orchard of the Pennsylvania State College. Likewise, intermediate stocks of Winesap at an elevation of 2,300 feet cost the owner all of his fine mature trees of Stayman Winesap. An intermediate stock of an unknown variety was responsible for injury to Northern Spy, McIntosh, and Stayman Winesap trees when trees of these varieties of a similar age, but not double-worked, showed little injury. In all three instances, the loose trunk bark did not extend above the upper graft union into the top variety.

Cherry trees, sweet and sour, but chiefly the former, suffered severely, especially when heavy 1935 crops were followed by premature defoliation by leaf spot. At one side of a young apple orchard just coming into bearing in which the loss of Wealthy and McIntosh trees was complete because of a loss of all trunk bark, half a dozen large sweet cherry trees were unharmed in wood, although all blossom buds had been killed. These sweet cherries had received two sprays after picking in 1935 which prevented leaf spot and held the leaves until they were frosted off. Just across the road from these cherries, every Baldwin tree in a 4-year-old planting was dead, or severely injured.

Practically all bearing peach trees in commercial orchards in the Pittsburgh area were either killed outright or so severely injured that their recovery was questionable. Non-bearing peaches showed much less injury, although twig killing or even a dying back of the tops to the snow line was common.

MARGINAL ZONE OF FRUIT TREE KILLING

The amount of injury in the Pittsburgh area was so great it was difficult to determine causal conditions. For this reason considerable time was spent in outlining and studying those marginal areas where slight environmental differences might be the cause of considerable difference in injury. The preliminary purposes of the survey in this zone were to determine the extent and nature of injury to tree fruits caused by the past winter, to find the conditions which are responsible for this injury, and to suggest feasible ways in which severe losses might be lessened in the future.

Injury from cold in the winter of 1935-36 was almost negligible in western New York. The freeze in early October had been nearly as severe here as in Pennsylvania. About a third of the leaves and much of the fruit dropped soon afterwards. The remaining leaves stayed on longer than usual. The temperature drop in January was not as extreme nor as rapid as it was further south. It is probable that this is the major factor responsible for the freedom from winter injury in this area.

Nearly all of the two northern tiers of counties in Pennsylvania lie in a district in which there was little or no injury to fruit trees. Fruit trees were unharmed at elevations of 1200 to 1400 feet when large numbers of *Prunus Pennsylvanica* were killed at elevations of 1700 to

1900 feet on nearby hills. In southern Lycoming County, near Williamsport, some bud killing on apples was noted but no injury to trunks or branches was seen.

In the western part of Pennsylvania, around New Castle about 60 miles north of Pittsburgh, there is a fairly well-defined, but narrow, transition zone extending east and west. Here the October frost was not so severe and the January drop was only 30 to 35 degrees. About half the bearing peaches were killed or seriously injured; old apple orchards escaped with little loss. In younger bearing orchards, especially those in cultivation, many Delicious trees had dead areas on the trunks. Baldwins were less seriously injured but showed weakened lower branches. In one orchard of York, three-quarters of the trees will die. Heavy fertilization and a large crop in 1935 were factors contributing to injury. This zone extends into Ohio where it includes the northern part of Columbiana and Mahoning Counties and then continues westward for some distance.

The small number of orchards and the rapid changes in elevation on the Allegheny Plateau in central Pennsylvania make it impossible to secure a clear picture of the winter damage to fruit trees in this region. Orchards near State College, which is in the geographic center of the state at an elevation of 1200 feet, suffered only minor losses, except the orchard on the College farm. In general, losses in central and south central Pennsylvania seem to be associated with growth conditions above the average rather than with a lack of vigor.

In the eastern third of the state the upper areas of both the Susquehanna and the Delaware Valleys escaped with little damage from the winter of 1935-36. This includes the fruit region around Wilkes-Barre and Scranton. The northern extension of the Shenandoah Valley from the Potomac to the Susquehanna at Harrisburg is called the Cumberland Valley; east of the Susquehanna River it is known as the Lebanon Valley and still farther east the Lehigh Valley, which extends to the Delaware River. These three valleys contain some of the most important fruit areas of the state. Going from north to south the first considerable injury to fruit trees from the winter of 1935-36 is found on entering these valleys at elevations below 1000 feet.

In the Lehigh Valley south of the Delaware Water Gap in the vicinity of Easton, which is situated on the Delaware River, peaches and sweet cherries showed some injury from the winter of 1935-36 but not as much as from the two previous winters. Eight to 10 miles west of the river at elevations around 400 feet the trunk bark split and sometimes rolled back in a small percentage of the Stayman Winesaps and McIntosh trees.

Allentown, 15 miles southwest of Easton, is the county seat of Lehigh County and the center of an important fruit area. Official minimum temperatures for this county on October 7, 8, and 9 were not much below 32 degrees F but there were killing frosts which brought down some of the leaves and caused a heavy drop of fruit on the 20th of October. On January 23, 1936, the temperature in one of the larger orchards in the southern part of the county dropped from 37 degrees above to 6 degrees below zero. Apple trees in this orchard had consider-

able bud killing and some trunk bark splitting, chiefly on trees lacking somewhat in vigor or standing in spots of poor soil. Golden Delicious trees had much trunk injury under unbroken bark. McIntosh exhibited both bud injury and trunk bark splitting. Commercial sweet cherries had so much fruit bud injury that there was a very small crop. Peaches showed branch killing and some trunk splitting but had a fair crop in 1936.

Across the road from this orchard, a block of 16-year-old apples had been over-cultivated for many years until serious soil erosion had lowered the vigor of the trees. Here 200 to 300 Grimes, Stayman Winesap, and Rome trees had the trunk bark split wide open. A younger and more vigorous block of Stayman Winesap, Baldwin, and Delicious showed little injury.

Two miles away from these orchards, a large peach orchard had been fertilized for a number of years with 1000 pounds of chicken manure per acre per year. The trees were heavily pruned each year and some of them had made as much as 5 feet of annual growth. Ninety per cent of these peach trees showed excessive trunk cracking but had less branch killing than in nearby peach orchards which had not been pushed so hard. Injury was least in those parts of the orchard which were least fertile. This orchard was interplanted with 7 and 9-year-old apples. Less than a dozen of these showed any signs of injury and then only slight trunk cracks.

In two large orchards north and west of Allentown at elevations of about 600 feet, alfalfa and clover sods have been used extensively and the soil is highly fertile. Less than 1 per cent of the trees showed either split trunk bark or dead areas under unbroken bark. Injured trees were scattered among several varieties but the heaviest loss was with Rome. Peach trees exhibited only a small amount of branch killing and produced a good crop in 1936.

In general in Lehigh County, apple orchards of average or better than average vigor had little or no injury; those on the poorer soils or in wet areas showed the most injury.

Reading, 35 miles southwest of Allentown, is the center of the Berks County orchards. All through this county the roadside Mazzard seedlings escaped with little damage; some of them had a full crop in the summer of 1936. Some cherries had been killed or seriously injured by the two previous winters, 1933-34 and 1934-35.

Two large groups of orchards in the southern part of the county include over a thousand acres of apples and peaches ranging from recently planted to 18 years old. Elevations range from 400 to 1000 feet and the sites have excellent air and water drainage. These orchards have been well cared for, the soil is fertile and well supplied with organic matter from sod rotations. Although peach trees showed much twig injury, a very good peach crop was harvested in 1936. Between 200 and 300 apple trees show trunk bark cracking or slightly sunken areas with dead cambium under them. Rome, Golden Delicious, and Gravenstein showed the most injury. The owners thought that a southwestern exposure combined with slightly poorer soil was responsible for this injury. No particular fertilizer application or cultural

practice seemed to be associated with an increased amount of injury.

A higher percentage of trunk injury on both apples and peaches was seen in an orchard along the Schuylkill River below Reading. Here excessive cultivation has resulted in heavy erosion and a low state of fertility in the orchard. Rome showed more injury than other varieties. Wet areas had more injured trees than those well drained.

North of Reading much of the injury attributed by the growers to the winter of 1935-36 was found to have been caused by previous winters. Less than 1 per cent of several thousand trees examined showed injuries due to the winter of 1935-36. Rome and Stayman Winesap both showed trunk and crotch injury. One block of McIntosh which showed much injury from previous winters also showed some caused by the winter of 1935-36. Peach trees had from two-thirds to a full crop in 1936. The only factor which seemed to be associated with apple tree injury was low vigor which was usually due to poor soil.

Halfway between Reading and Philadelphia on the Piedmont side of the last range of hills lies an area of local market orchards. This area is in a quarter circle centering on Philadelphia and running from New Jersey to the Maryland line. The apple and peach orchards are usually small—from 5 to 25 acres—and are mostly in sod or weeds. In these orchards the winter of 1935-36 caused almost no injury. However, when apple trees 10 to 20 years old in full bearing had received late cultivation or excessive fertilization, dead areas under unbroken trunk bark were common, especially on Rome and Golden Delicious.

The record in one Piedmont orchard not far from the Schuylkill River near Norristown was especially interesting. The October frost had caused considerable defoliation and all varieties but Rome had dropped heavily around the 21st. These trees had always been rather heavily pruned and fertilized; in 1935 they received from 8 to 12 pounds of calcium cyanamide early in March. At one time the orchard had been cultivated to a point where erosion was starting; since then it has been in clover sods, usually disced in the spring. Nearly all trees had a heavy crop in 1935. Eighteen-year-old Romes showed serious trunk injury from the winter of 1935-36 but some 12-year trees showed heavy trunk injury from one of the two previous years only. Likewise, some Stayman Winesap and Jonathan showed trunk injury from the winter of 1935-36 and in one block, lower branches on Stayman Winesap and Yorks were dying. McIntosh, Grimes, and Baldwin showed little, if any, injury.

It seems highly probable that the excessive injury to Rome in this orchard and indeed in much of the state was due to the heavy crop and the fact that the fruit was not picked until November; it was the last fruit to be harvested. However, in addition to this factor, the orchard has been pushed harder by pruning, cultivation, and fertilization than most of the orchards in the county.

The performance of two nearby peach orchards is interesting. In both orchards the trees ranged from 8 to 16 years old and were of the same varieties. In the one, the orchard was cultivated throughout the early summer and seeded to rye in October; in the other, cultivation was stopped in June and a heavy growth of weeds covered the orchard

through the winter. Where the late cultivation created conditions unfavorable for tree maturity, two-thirds of the trees were killed or seriously injured. Where the heavy weed growth was undisturbed, there was no killing of trees and a good crop was produced in 1936.

In all the southeastern section of Pennsylvania, the study of winter injury to fruit trees due to low temperature in 1935-36 was complicated by trunk injuries caused by low temperatures in the winter of 1934-35. Typically these injuries produced dead areas covered by unbroken bark and many growers failed to detect this until the dead bark began to come off in 1936, so that the damage was attributed erroneously to the winter of 1935-36. The low temperatures of 1934-35 came on January 28 and February 7 when minimums of 15 to 18 degrees below zero throughout this section were from 8 to 12 degrees below those at State College and equaled or approached closely the record lows.

Very little difference was found in the Cumberland Valley as compared to the valleys to the northeast. Although sweet cherries showed considerable damage from other winters, that of 1935-36 did not injure them enough to prevent many having a full crop the following summer. The smaller, 5 to 10 acre, apple orchards which are usually considerably neglected and in permanent sod show almost no injury from the winter of 1935-36, though many lower branches are dying because of injury from other winters. On the other hand, in well-cared for apple orchards, considerable injury seems to be associated with areas of poor soil which produces trees of low vigor. Also, there has been much heavier killing in low areas of peach, cherry, and apple orchards. There are likewise a few cases of winter injury to apples where too high a scale of fertility delayed tree maturity.

Injury to peaches in Franklin County in the lower Cumberland Valley will run somewhat higher than with apples. In general all peaches had some branch and bud killing, yet the county had about two-thirds of a full crop of peaches in 1936. Many trees show trunk bark splitting but otherwise seem in fair condition. Trunk splitting appeared to be more severe with vigorous peach trees while branch killing was greater with less vigorous trees.

WINTER INJURY IN THE NORTHERN PANHANDLE OF WEST VIRGINIA AND OHIO

The older orchards in the West Virginia Panhandle seem to have escaped uninjured from the winter of 1935-36 but one large orchard just coming into bearing on the hills near Chester will lose several thousand trees. Here a southwestern exposure, a full crop, and rather heavy fertilization seem to be factors in accentuating injury.

From Wheeling westward to Zanesville, Ohio, and northward to within 25 miles of Lake Erie there is extreme variability in the amount of winter injury and an almost equally great variability in the environmental conditions in these orchards. At Wooster, frost cracks showed in tree trunks a few days after sub-zero weather during Christmas week. On January 22, 1936, there was a 47 degree drop in 12 hours accompanied by a wind as high as 37 miles per hour from the northwest. The drop in early October, 1935, froze grapes on the vines. Similar weather conditions held for a considerable area around Woos-

ter except that the lowest temperature reached varied from 16 degrees below zero to 26 below.

In one orchard near Barnesville, Ohio, in that part which had a northwest slope, half the Staymans and Delicious were seriously hurt and the McIntosh and Jonathan showed considerable trunk injury while these same varieties on a southwest slope showed very little injury. On the north and south ridges which outline the Cuyahoga Valley north of Akron, orchards with western exposures were much more severely injured than those at the top of the ridges or on the eastern slopes. Varieties showing injury here were Wealthy, Golden Delicious, Red Delicious, King David, and McIntosh. Throughout all this area there are many orchards in which the factors which seem responsible for damage from the winter of 1935-36 are those factors which delay tree maturity—heavy crop in 1935, late cultivation, heavy pruning, excessive fertilization or too low a plane of fertility, and wet areas. When any of these factors was combined with an unfavorable exposure the winter damage was usually severe.

SUMMARY OF CONDITIONS WHICH CAUSED INJURY FROM THE LOW TEMPERATURES OF THE WINTER OF 1935-36

The manifestations and the apparent causes of winter damage differed so from one area to another that, at first, the survey seemed only a collection of conflicting evidence but as soon as it was realized that tree maturity was the one common factor the evidence became cumulative rather than conflicting. Hardly any of the injury from the winter of 1935-36 was due to excessively cold weather alone. Some of the orchards injured have been subjected to temperatures 10 to 20 degrees lower during one or both of the two previous winters.

Apparently throughout most of the northeastern states and into the Ohio Valley, fruit trees went into the winter of 1935-36 poorly matured. There was a heavy crop in 1935. The unseasonable freeze in early October injured the leaves and checked the normal maturing process. The sudden drop on January 22, starting from above freezing and going down to 10 to 20 degrees below zero, was too severe for immature tissues. The higher the initial temperature, the more rapid the drop, the lower the minimum, the greater the exposure to heavy winds when these low temperatures were reached, the greater the injury.

Tissues injured are those typically slow to reach maturity—the bases of the buds, the tissues of the inner portions of large crotches and of the lower trunk of most varieties, and the sapwood of the lower branches in Baldwin and Rhode Island Greening.

Trees were injured both because they were too vigorous and because they were too low in vigor. Excess fertilization, heavy pruning, late cultivation, thin soil, spray injury, heavy bearing, all caused damage to trees in one place or another.

In the case of Rome, late picking seems to have accentuated the injury and in a few orchards there was evidence that early pruning had caused damage.

Time and amount of fertilizer applications seem to have influenced the degree of injury only when they have increased or decreased the maturity of the trees. Source of fertilizer does not appear to have been a factor in modifying tree injury.

Unusual and Severe Winter Injury to the Trunks of McIntosh Apple Trees in New Hampshire

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WINTER injury to the trunks of apple trees has been reported many times in the horticultural literature. Among others, Balmer (2), Selby (6), Grossenbacher (4), Bradford and Cardinell (3) cite severe and extensive injuries of this type. The writers venture to add to this already voluminous literature because of rather unusual circumstances under which the injury occurred in New Hampshire last winter, and because it appears to be somewhat distinctive in character.

The injury was first noted at Wolfeboro in an orchard of mature McIntosh trees under sod culture. The soil is of rather low fertility and in places poorly drained, but the orchard is well cared for and has been vigorous and productive. A dusting schedule is followed and, possibly due in part to the accumulation of sulphur in the soil, the pH is low, ranging from 4.65 to 5.00. The sod is suffering and in places is giving way to acid tolerant plants.

In early June leaves on some trees that had blossomed and set fruit in an apparently normal manner showed a chlorotic condition. The bark, although not split or discolored, was found to be dead near the base of the trunk. As the summer progressed, the foliage of these and other trees began to turn yellow, and it was found that many more were affected than was at first supposed. Near the end of the season, the foliage was often purplish. By September, the bark tended to discolor and sometimes to shrink and form narrow cracks 3 to 18 inches long. The wood beneath was entirely dead, and of a chocolate brown or purplish color. Although without live phloem or xylem, the trees produced practically a full crop. The apples had nearly normal size, and normal color except that the shade was a little pale. They matured 3 to 6 days earlier than usual. A typical tree as it appeared in October is shown in Fig. 1.

In October a detailed examination showed that out of a total of approximately 400 McIntosh trees about 75 were nearly completely girdled, and in 45 of these the injury extended into the branches so that it is impossible to bridge-graft; about 60 trees had dead areas extending one-third to three-quarters of the way around the trunk; 54 more had injury covering less than one-third of the trunk. It has not been noted on any tree more than 2 inches below the ground and usually it stops sharply at the ground line. No side of the trunk is immune. The variety Delicious also shows the injury badly. Wealthy trees topworked about 1925 to McIntosh have the same trouble.

The McIntosh in New Hampshire is very hardy and over a 40 to 50 year period no such severe injury has previously been recorded. During the winter of 1933-34 McIntosh trees in some cases with practically no snow cover, were exposed to temperatures of -30 degrees F. Since the injury observed this season extends to the ground line, it is believed that it occurred either before the first deep snowfall on January 18 or subsequent to the sudden melting of the snow on

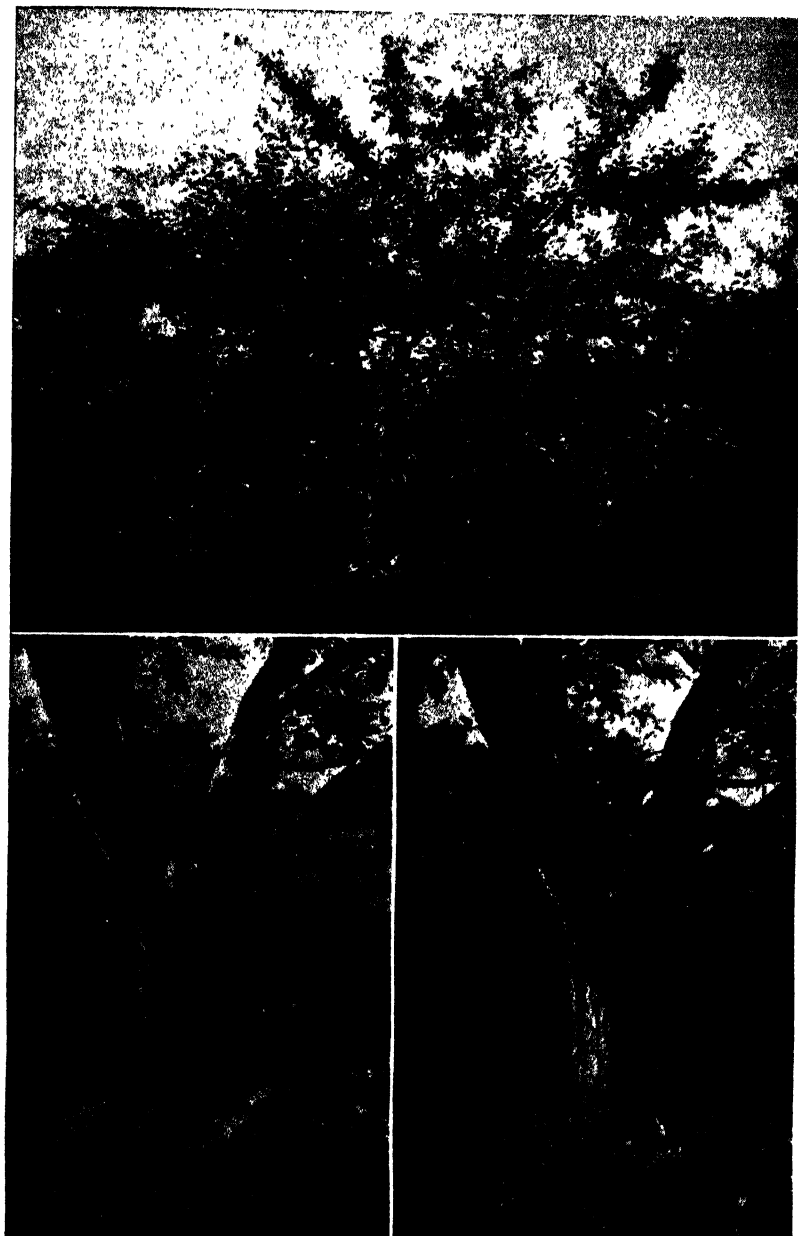


FIG. 1. A typical injured tree. Above—as it appeared after the crop was harvested. Lower right—trunk as it appeared October 10. Lower left—same after stripping away the dead bark.

March 11 to 13, 1936. If so, it was caused by a temperature not lower than 0 degrees F. Throughout the whole winter, no very severe weather occurred, and in 1936 Elberta peaches in most New Hampshire orchards bore a full crop. A situation in which Elberta peaches are uninjured but McIntosh trees die, is most unusual.

Bark splitting has occurred at intervals especially on trees fertilized with poultry manure. Some of this injury occurred following the severe winter of 1933-34. However, in all splitting previously observed, the bark was alive and if tacked to the tree often re-united with the trunk. If not tacked down, growth tended to warp it away from the wood. Trees were rarely if ever completely girdled. Fifty trees in the orchard under discussion show evidence of callus over wounds of this character. Injury as reported here in which the bark and wood are entirely dead have hitherto been unknown on McIntosh in New Hampshire.

Injury to the trunk and lower branches as severe as this has occurred in New Hampshire in recent years on more tender varieties, but so far as we have observed always accompanied by damage to spurs and branches. In no case has such severe injury occurred to the base of a tree when at the same time *the spurs were so completely uninjured as to permit a full crop of fruit to set and mature.*

With minor exceptions, it has been found to date in New Hampshire only on trees fertilized in the fall with some form of available nitrogen. Its occurrence is shown in Table I, which includes all New Hampshire orchards known to have been fall fertilized. In every case except the Farmer orchard, the shift from spring to fall fertilization was made in 1935 and therefore the trees received two applications that year. The soil in the Goodwin orchard is even more acid than that in the Foster orchard, but it is better drained. The soils of the other fall fertilized orchards are better, as evidenced by growth of the sod, and are probably equal to those of the average New Hampshire orchard. In the Farmer orchard, the injury was found in a block where soil conditions are good except that drainage had been impaired through damage to a tile. In the Haskell orchard, the "North" block adjoins the "Middle" block, but is at a lower elevation. The five injured McIntosh trees in the middle block are all in one wet corner.

More than 40 spring fertilized orchards not listed in the table were examined without finding any of this injury. Special attention was paid to orchards near injured ones. The Hale orchard, which is immediately adjacent to the Foster orchard and under identical soil and drainage conditions is mentioned in the table as an example. However, it has never been fertilized enough to make it vigorous or productive. Spraying is practiced rather than dusting.

This type of winter injury has been ascribed to very low mid-winter temperatures or lack of maturity of the tissues followed by low autumn and early winter temperatures. Immaturity has been reported as associated with heavy rain or irrigation in late summer and fall, a short and cool, wet growing season, or late cultivation. The varieties trunk injured are usually tender ones.

During the autumn of 1935, there were no serious early freezes. The crop, which was generally rather heavy, ripened normally, and the

TABLE I—OCCURRENCE OF A PECULIAR TYPE OF TRUNK INJURY TO APPLE TREES IN NEW HAMPSHIRE 1935-36

Orchard	Location	Varieties	Number of Trees	Age	Per Cent Injured*	Fertilizer		Pounds per Tree
						Kind	Date Applied†	
<i>Fall Applications</i>								
Foster.....	Wolfeboro	McIntosh	426	22	44	Cyanamid	Oct. 15	5-8
Foster	Wolfeboro	Delicious	52	22	63	Cyanamid	Oct. 15	5-8
Potter	Durham	McIntosh, Cortland	600	6	3	Cyanamid	Oct. 15	1½
Goodwin	Wolfeboro	Delicious, Mc. Intosh	850	20	1	Cyanamid	Oct. 15	5-7
Whiting	Wilton	McIntosh	1 200	8-15	0-3	Cyanamid	Oct. 15	2-5
Farmer	Hampton Falls	McIntosh	15,000	15-23	0-1	Cyanamid	Nov. 10	5-6
Walter Bros.	Wolfeboro	McIntosh	200	25	3-4	Nitrate of Soda	Oct. 15	6
Rowe.	Stratham	McIntosh, Cortland, et al	500	16	0	Cyanamid	October	2½
Haskell	Chesterfield	McIntosh, North Block	72	10	39	Cyanamid	Nov. 20	5
Haskell	Chesterfield	Winter Banana, North Block	8	10	38	Cyanamid	Nov. 20	5
Haskell	Chesterfield	Winter Banana, Middle Block	35	15	0	Cyanamid	Nov. 20	7
<i>Spring Applications</i>								
Haskell	Chesterfield	McIntosh, Middle Block	125	15	4	Cyanamid	Spring	7
Haskell	Chesterfield	Winter Banana, Middle Block	36	15	0	Cyanamid	Spring	7
W. L. Hale	Wolfeboro	Delicious McIntosh, Cortland	400	10	0	Nitrate of Soda	May 1	2

*Percentages are based on counts in the Foster, Potter and Haskell Orchards,—others estimated

†Dates are approximate except in the Haskell Orchard

leaves fell at the usual time. August was rather dry, September rainy, with October dry and sunshiny. To all appearances, the trees had matured normally. However, November was very rainy and warm. The November temperature was 4.3 degrees F above the normal. Maximum temperatures at Concord November 1 to 15 ranged from 43 to 72 degrees F with maxima below 50 degrees F on only 4 days. From November 16 to December 3, the maximum ranged from 31 to 59 degrees F with maxima below 40 degrees F on 6 days. Noyes (5) states: "Only four other Novembers have been as mild since 1888, when Section averages were first compiled, namely in 1896, 1902, 1927, and 1931." The first week of December was relatively cold with minima at Concord of 5 degrees F on the 4th and 5th, and 4 degrees F on the 6th. Zero and near zero temperatures occurred the last week of December. At other stations in southern New Hampshire, zero temperatures occurred early in the month and from -1 to -5 degrees F during the last week. Early January was warmer than usual, but minima of -11 to -12 degrees F were registered the last week of the month. February was cold with only 7 days with temperatures above 32 degrees F and 6 days with below zero temperatures. At Concord, a minimum for the winter of -16 degrees F was recorded on February 20th. On the same day, it was -20 degrees F at Durham and -25 degrees F at Keene, but at that time the injured trunks were deeply covered with snow. Following the sudden melting of the snow in March, the weather was unseasonably warm. A temperature of 25 degrees F on May 15 is the lowest subsequently recorded.

The writers feel that, although the evidence is by no means conclusive, the possibility of fall applications of chemical nitrogenous fertilizer being one of the factors which may predispose apple trees to winter injury merits further observation. Aldrich (1) and Smith (7) have shown that apple roots absorb nitrogen during the winter months in the latitude of Maryland. Even so it is difficult to understand how it could cause cell activity at the base of the trunk when applied for instance as late as November 20. Certainly if fall fertilization can cause this trouble, the conditions under which it may do so should be defined. The problem is now being studied at the New Hampshire Experiment Station with the cooperation of the American Cyanamid Company.

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December Pruning in 1935 Results in Severe Injury to Jonathan and Stayman Trees at Lafayette, Indiana

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IT is very difficult to take care of the necessary pruning work in a large apple orchard if all of the work is delayed until mid-February. In Indiana it is common practice to start the pruning work in late November, and this procedure has rarely resulted in noticeable injury in the case of most of our commercial varieties.



FIG. 1. The two Jonathan rows in the foreground were given a moderate to heavy pruning in early December, 1935. The trees in the background were not pruned. Only one of the 14 unpruned trees showed signs of winter injury. Picture taken in September, 1936.

In December, 1935, several student pruning laboratories were conducted on a block of 10-year-old Stayman and Jonathan at Lafayette. These particular trees had received very little pruning for a number of years and were over thick with secondary branches originating near the crotches of the trees. The pruning resulted in quite a large number of 1- to $1\frac{3}{4}$ -inch cuts, located mainly within 4 feet of the crotch of the trees, accompanied by an average amount of thinning out of the tops. The last pruning laboratory was on December 6.

A severe period of cold weather began on January 22 with 10 out of 11 days within a minimum temperature of 0 degrees F or lower. This was followed by unusually low temperatures up to February

20. Minimum temperatures, Fahrenheit, during this period were as follows:

January 22	-15	February 1	- 5
January 23	-20	February 5	- 8
January 24	-16	February 6	- 1
January 25	0	February 9	- 7
January 26	- 6	February 10	- 5
January 27	-11	February 11	- 5
January 28	- 8	February 15	- 2
January 30	-11	February 18	-12
January 31	-11	February 19	- 4

The December pruned Jonathan seemed to suffer somewhat more than the Stayman, but both varieties were injured to the point that many of the trees were entirely dead by September, 1936. Of 48 December pruned Jonathan only five showed no visible sign of injury, and four out of the five had been lightly pruned. Fourteen Jonathan trees were not pruned either in the fall or spring and of these only one showed evidence of slight crotch injury. The amount of injury on both varieties was in direct proportion to the severity of the pruning. Observations made in the springs of 1918 and 1930 indicated quite severe

injury from all pruning of Stayman in southern Indiana.

Fourteen-year-old Stayman, Winesap, Delicious, Rome, and Golden Delicious were also quite heavily pruned in December, 1935, at Lafayette. No visible injury could be detected on Rome, Delicious, and Grimes and only slight injury on Golden Delicious. Stayman trees were severely injured and some trees were completely dead by September, 1936, and others so badly injured about the crotches that the trees are practically worthless. Many Winesap trees in this same block were also injured but not nearly to the extent of that on the Stayman. It should also be stated that none of the pruning wounds on these trees were painted until late in the spring of 1936. The amount of serious injury near and especially below the



FIG. 2. This 1-year-old Jonathan tree was given a moderate pruning in December. Nevertheless it is evident that the pruning cuts in the vicinity of the crotch of the tree resulted in a very severe form of winter injury.

pruning wounds on these trees were painted until late in the spring of 1936. The amount of serious injury near and especially below the

pruning cuts might have been substantially reduced had these cuts been painted with a waterproof paint immediately after they were made.

Reports on other commercial orchards in the State indicated that Baldwin, Hubbardston, and York Imperial all showed more or less winter kill in the summer of 1936, especially in low pockets in the orchard. A rise of even a few feet in the orchard site often entirely eliminated visible injury.

It would seem from these observations during 1 year that when heavy pruning is to be practiced, the work should not be done until late February. Fall pruning of Stayman, Jonathan, Winesap, York Imperial, Hubbardston, and Baldwin may result in severe injury if followed by prolonged periods of sub-zero temperatures. Where the amount of pruning requires that the work be started in November or December, it would seem best to work first on such varieties as Rome, Delicious, and Grimes. Still another possibility would be to confine the pruning to mature trees where the pruning cuts would be relatively small and mainly in the outer surface of the trees, well removed from the crotch and lower parts of the scaffold branches.

Some Observations and Current Studies of Winter Injury to Apple

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WINTER injury to apple in Maine is no new thing. Literature records the occurrence of severe damage in the winters of 1856-7, 1863-4, 1903-4, 1904-5, 1906-7, 1917-8, and 1933-4. A survey was made by the Maine Department of Agriculture in the summer of 1934, which embraced 889 commercial orchards and showed that 40.3 per cent of the bearing apple trees and 3.9 per cent of the non-bearing trees were injured. Table I summarizes that survey.

TABLE I—SUMMARY OF MAINE STATE DEPARTMENT OF AGRICULTURE
WINTER INJURY SURVEY OF 1934* (SUMMARY OF 10 VARIETIES)

Variety	Number Growers	Number Trees	Trees in Bearing			Trees Not Yet in Bearing		
			Total	Injured	Per cent Injured	Total	Injured	Per cent Injured
McIntosh .	666	133,916	79,636	2,063	2.6	54,280	936	1.7
Cortland .	95	10,493	2,184	170	8.0	8,309	173	2.1
Delicious .	252	18,959	13,771	1,769	12.8	5,188	529	10.2
G. Delicious	72	8,301	2,565	323	12.6	5,736	356	6.2
Spy. . . .	473	27,376	22,133	5,150	23.3	5,243	164	3.1
Baldwin . .	786	163,520	158,736	109,598	69.0	4,784	898	18.8
Gravenstein . . .	221	5,193	4,137	2,543	61.5	1,056	107	10.3
Wealthy . .	299	15,795	13,864	925	6.7	1,931	168	8.7
Ben Davis .	388	47,502	47,485	18,892	39.8	17	0	0
Stark . . .	386	33,554	33,472	11,053	33.0	82	8	9.8
Totals . .	889	464,609	377,983	152,486	40.3	86,626	3,339	3.9

*Compiled by A. K. Gardner, Extension Crops Specialist.

Following the winter of 1906-7, a survey by Hitchings (4) of 950 orchards showed that of the bearing trees 11 per cent had been injured. His findings by variety were comparable and similar to those presented in Table I; Baldwin and Ben Davis were injured most, with Northern Spy and R. I. Greening not far behind.

In the winters since 1933-4 the exceptionally severe damage of that year has been aggravated. Furthermore, field observations during the growing seasons of 1934 and 1935 made it clear that the survey method had underestimated the extent of the damage. Many trees that leaf out in the spring following a test winter die as the growing season advances (Fig. 1, left). Nevertheless, the rating of varieties remains about the same. A compilation of such field observations and of the findings of the two surveys mentioned indicates that some of the definitely non-hardy varieties in Maine are Baldwin, Gravenstein, Ben Davis, Stark, Northern Spy, Tolman, St. Lawrence, King David, and Winter Banana, most of which have been rather prominent in the composition of Maine orchards.

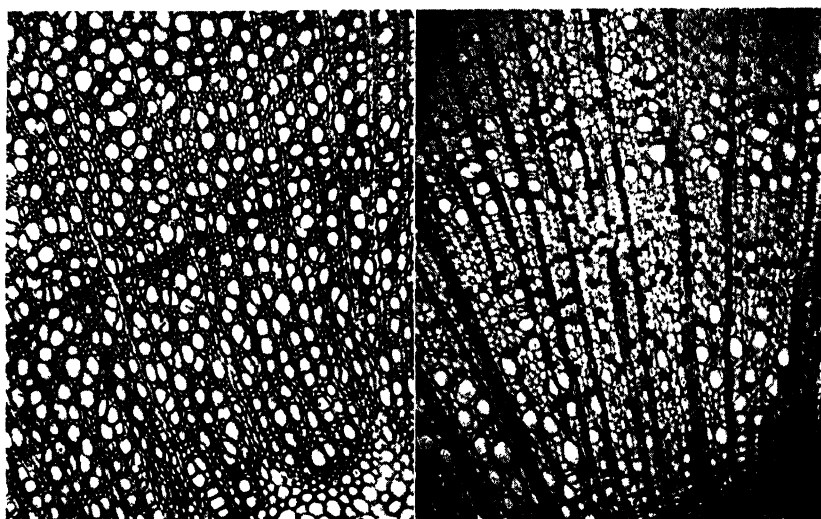


FIG. 1. Injured and uninjured Gravenstein trees. Photographed in September, 1934.

During the winters of 1934-5 and 1935-6 an attempt was made to determine the relative hardiness of a number of apple varieties by artificial freezing. The method employed is detailed in a manuscript not yet published (7) which shows that low temperature injury in apple trees is characterized by the killing of parenchyma cells and the occlusion of vessels by a substance resembling wound gum. These anatomical characteristics were noted in field samples collected during the growing season of 1934 from trees injured the previous winter (Fig. 2). Artificial freezing tests showed that these characteristics could be reproduced under laboratory conditions. Thus by the artificial freezing of twigs and the subsequent examination of microscopic sections, a ranking with respect to hardiness was indicated that agreed closely with that established by field conditions.

In fact, many investigators have found a close correlation between the resistance of varieties to artificial freezing and to severe field conditions. Among these may be mentioned Hildreth (3) for apples and Martin (6) for wheat. In general, the freezing tests conducted in 1934-5 and 1935-6 indicate that in Maine the Cortland, Macoun, McIntosh, Milton, and Oldenburg varieties are hardy in comparison with Delicious, Golden Delicious, Haralson, Northern Spy, Orleans, Stayman, and Wealthy, which are intermediate, and with Baldwin, Ben Davis, Gravenstein, St. Lawrence, and Stark, which are non-hardy.

In the summer of 1934, Maine orchardists congratulated themselves that McIntosh, their favorite and leading commercial variety, had stood the test of the preceding winter for hardiness. But the spring of 1935



A B
FIG. 2. Cross sections of Golden Delicious twigs.
A, Uninjured. B, Injured. 125 $\times$.



FIG. 3. Trunk injury to McIntosh in the
Agricultural College Orchard at Orono.

disclosed a different situation. In some commercial orchards of southern Maine almost 90 per cent of the bearing McIntosh trees had patches of dead bark on their trunks, and in the College orchard at Orono, of a total of 110 McIntosh trees, all but five showed such trunk injury (Fig. 3). Certain observations suggest that this injury may have had its origin in the winter of 1933-34.

The spring of 1936 disclosed still another type of trunk injury to varieties considered hardy in the State. It was most common on young trees of McIntosh and Cortland and was characterized by the bark at the crown showing a brown discoloration and being depressed and separated

from the healthy bark. The affected bark sometimes extended upward into the branches and frequently girdled the tree completely.

The alarming extent of trunk injury to McIntosh and Cortland, so prominent in recent plantings, and the fact that trunk and crotch injuries have come to be recognized as the ultimate causes of death to trees of many varieties, have again focused attention, in Maine as elsewhere (5, 8), to the possibilities of top- and double-working in order to secure the advantage of superior hardiness of trunk. This had been recommended and practiced by Maine orchardists as early as 1863 (2). The authors of this paper have not observed winter injury to roots; hence the emphasis upon trunks.

The statements of Filewicz (1) of Poland, that a tender scion variety will take on the hardiness of the stock within 5 years, and that a tender trunk may in 5 to 10 years acquire the hardiness of hardy scions top-worked upon it, are at variance to the opinion commonly held, but deserve careful attention. In 1934 a Maine orchard was found in which the owner had 6 years before top-worked about one-half of a block of Baldwins to McIntosh. The trees with McIntosh tops had survived the winter of 1933-4, whereas the adjacent trees with their original Baldwin tops had been killed. This and similar observations on smaller numbers of trees in other orchards, tend to confirm the second statement of Filewicz, but the killing of Ben Davis trunks under McIntosh tops, also observed, weakens his case.

A stock of nursery trees of Virginia Crab, Hibernial, Haas, Sheriff, and Antonovka, thus far on Kansas-grown seedlings, is being developed at Orono both by purchase and by propagation. Trees of Virginia Crab and Hibernial were set in two orchards in the spring of 1936 and a few branches were budded in the late summer. Through the courtesy of Dr. H. B. Tukey and Dr. F. E. Gardner some of the East Malling clonal types and some of those developed by the United States Department of Agriculture have been received and are experiencing their first winter in Maine. After some preliminary skirmishing in an attempt to eliminate the obviously unsuited material, it is intended to launch pretty intensively into a project of testing present popular varieties on the more promising rootstocks and intermediate stocks.

The severity of damage to present commercially important varieties has led to a new emphasis being placed upon hardiness in the apple-breeding work of the Maine Station. The most important objective is a hardy, late-keeping variety of good quality both for cooking and dessert. By the application of the artificial-freezing test to progeny which have satisfactory growth characteristics, those that lack hardiness may be eliminated promptly, thus making it possible to speed up the work.

It is proposed, further, to apply the artificial freezing test to samples of the seedling populations from controlled crosses in the attempt to determine which parents may be depended upon to produce hardy seedlings for stock use.

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Frost Rings in Hardy Varieties of Apple

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AREAS of parenchyma-like cells occurring irregularly in woody tissue have long been known. In cross sections of woody stems, they may appear as flecks or streaks or as partial or complete rings of varying widths, concentric with the growth rings. They have been attributed to several causes such as lightning, frost, drought, and the proliferation of adjacent cells into cavities left by cambium-mining insect larvae.

The rings described here are designated as frost rings, since they are believed to have been caused by low temperature. They were found in the trunks of low-headed, mature trees of McIntosh, Red Astrachan, Delicious, and Northern Spy in the orchards of the New Hampshire Experiment Station at Durham, New Hampshire. These varieties are among the more hardy for the region. They showed little or no external signs of injury following the severe winter of 1933-34, when a temperature of -31 degrees F was recorded on December 30 and of 1934-35 when -35 degrees F occurred on January 31.

These observations were made on samples taken in 1935 primarily for a study of the amount and type of xylem growth. A Swedish increment borer was used, with which were secured cylindrical pieces of wood 0.19 inches in diameter by about 1 inch in length, including portions of from two to six growth rings. The samples were taken from the north and south sides of the trunk somewhat below the lowest main branch. Each succeeding sample was taken to one side of and at least 1 inch away from any previous sampling wound. Thus the total area from which samples were taken covered about 36 square inches.

Frost rings have been observed in all varieties studied. In all cases they occur at the beginning of the season's growth, being bordered on the inside by the late wood of the previous year. Rings formed after one or more rows of normal cells had been laid down by the cambium have not been found.

A constant characteristic of the rings is the broadened or proliferated appearance of the wood rays. The cells between them may have retained their protoplasmic contents and contain storage materials or they may have differentiated normally. In either case, normal differentiation is gradually resumed until the wood formed toward the end of the growing season seldom shows abnormalities.

Varying degrees of severity of frost ring have been found. In the least severe, only a small number of cells about some of the rays are parenchymatous. In others, the rays have proliferated considerably but normal wood elements are present between them. In the most severe, a complete band of parenchymatous wood is present.

Table I shows the total number of observations of all varieties for each year studied together with the per cent of frost rings observed. Each growth ring in each sample constitutes one observation. Thus, a sample taken in the fall of 1935 and extending into the wood of 1932 would furnish three observations. 1932 not being counted since the beginning of its early wood would not be present.

TABLE I—OCCURRENCE OF FROST RINGS IN TRUNKS OF MCINTOSH, RED ASTRACHAN, DELICIOUS, AND NORTHERN SPY

Year	Number of Observations	Per Cent Showing Frost Rings
1931	32	41
1932	67	10
1933	105	45
1934	121	72
1935	76	47

There are several reasons why it is believed that these frost rings were not caused by late spring frosts: (a) they occur at the beginning of growth rings, in all cases being bordered toward the inside by the late wood of the previous season; (b) they are comparatively rare in the wood of 1932, the only year a late spring frost occurred in this orchard during the period studied; (c) they are abundant in the other years studied.

While exact evidence that the rings were not caused in early spring is lacking, their preponderance in 1934 and 1935, the years of lowest temperatures, leads to the conclusion that extreme cold during the dormant season may be a causal factor. But from the fact that there are more frost rings in 1934 when the minimum temperature was -31 degrees F than in 1935 when it was -35 degrees F, it seems that the actual degree of cold is not decisive.

There are two conditions that may have influenced the susceptibility of the trees to frost ring formation in 1934; (a) the extreme cold came early in the season, before the trees had attained their greatest resistance, and (b) the trees produced a heavy crop in 1933. That early cold and heavy crop production increase the susceptibility to winter injury is well known. Frost ring formation from extreme cold may be affected by the same factors as crotch and crown injury, black heart, and killing back.

The high per cent of frost rings in 1933, a year with neither late spring frost nor unusually low winter temperatures, is due to their abundance in McIntosh, a variety that seems particularly susceptible. Frost rings have been found in every growth ring studied, although they are not present in every sample. Seventy-eight per cent of the 104 observations show frost rings.

McIntosh is also susceptible to the type of winter injury known as bark-splitting. There may be some structural peculiarity in this variety which predisposes it to both types of injury. This point should be investigated. The wood of McIntosh is very hard, offering the most resistance to the increment borer and being the most difficult to section.

In two Red Astrachan trees sampled throughout the season, frost rings were found only in the growth rings of 1934 on the south side of the tree with one exception, a slight fleck appearing in the 1934 wood of one sample from the north side of tree BF 106. In samples taken from two other Red Astrachans in December 1935, only one slight fleck occurred, in the 1934 wood of the north side of BF 58. Out of 82 observations, 13 per cent show frost rings.

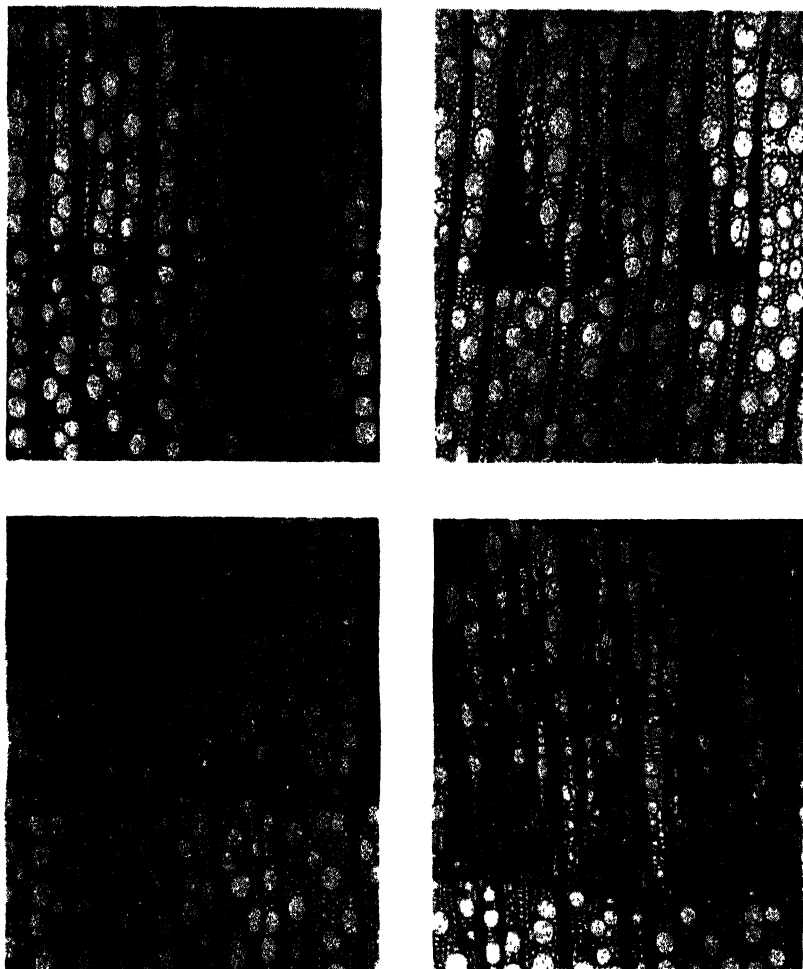


FIG. 1. Photomicrographs of early wood (above) bordering the late wood of the previous season from trunks of mature apple trees: upper left, Red Astrachan, normal; upper right, McIntosh, a frost ring in which normal tissue is present between parenchymatous areas; lower left, McIntosh, a complete narrow frost ring; lower right, Red Astrachan, a rather severe frost ring.

In Northern Spy, the complete absence of rings in 1932 is noteworthy, as is also the fact that the severity is greatest in 1934. In 128 observations, frost rings have been found in 42 per cent. The data for Delicious are similar to that for Northern Spy, injuries being most abundant in 1934 and lacking in 1932. Fifty-one per cent of the 87 observations contain frost rings.

The frequency of occurrence of frost rings appears to depend some-

what on the variety. McIntosh seems especially susceptible and Red Astrachan only slightly so. Delicious and Northern Spy occupy intermediate positions. Although only four trees of each variety were studied, the close agreement among each four seems to justify these statements.

From these observations it is shown that winter injury may be observable in the anatomical structure of apple tree trunks, when no external symptoms are evident. The physiological importance of such injury is not known.

Double Growth Rings in Red Astrachan

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ALTHOUGH the term "annual ring" as a designation for a ring of wood laid down during one growing season is widely used and generally accepted, it is not an accurate term, since rings may be omitted during certain years and also more than one ring may be formed during a single year. It is well known that double rings may be formed as a result of defoliation or of seasonal variation in environmental conditions such as temperature and precipitation.

Sorauer (1) has said, "To the causes which may induce the formation of false annual rings, I was able in the year 1886 to add the effect of frost". Sorauer does not mean that frost causes the cambium to finish one wood ring and begin another, but that after a late frost has killed the young leaves, cambial growth is retarded or checked. When new foliage has been produced, cambial growth is resumed and a new wood ring is begun.

In cross-sections from trunks of four Red Astrachan apple trees, there appeared a pattern of three rings, one moderate in width, one very narrow, and one wide, the width of the wide ring being greater than the combined widths of the other two. Apparently one ring was formed in the off year and two in the bearing year. In samples taken in September 1935, the bearing year, a wood ring of moderate width had just been concluded, and a new ring was being laid down. In later samples a complete narrow ring was present.

No such pattern of three rings was found in samples from the trunks of McIntosh, Delicious, Northern Spy, and Cortland in the same orchard. In these varieties it was found that in general wider growth rings were laid down in "off" years.

The crop of the Red Astrachan trees matured and was removed in August, while those of the other varieties studied were not harvested until September or later. This suggested that cambial growth might have been checked by the utilization of most of the photosynthate in the maturing fruits. The growth ring of moderate width followed by the very narrow one always occurred in a crop year, the wide ring therefore, having been formed in the "off" year. "Thus to the causes which may induce the formation of false annual rings" has been added the harvesting of a mature crop in midsummer.

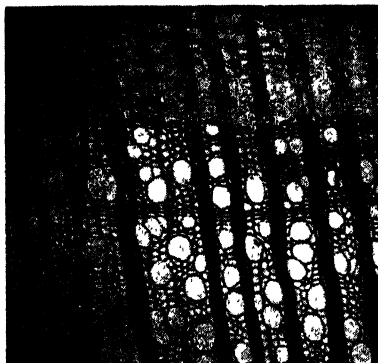


FIG. 1. Photomicrograph of wood, cambial region, and bark from Red Astrachan tree December, 1935. Narrow growth ring formed after harvest, wood formed before harvest below, and bark above.

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Relation of Shoot Growth to Setting and Weight of Fruit in the Filbert

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IN an earlier report (1) on filbert growth it was shown that there is a close correlation between the length of a shoot and the area of the leaves attached to the same shoot. Therefore, the length of shoot growth was used in preference to the leaf area for all subsequent work since such use furnished a much more rapid method of collecting data.

Filbert pistillate flowers are produced by both lateral and terminal buds on the growth of the previous year, called here "primary" growth. On vigorous trees a larger proportion of such buds are lateral than on less vigorous trees. The fruit clusters are developed coterminally on secondary growth, originating from the buds producing the pistillate flowers. Besides the current fruit-producing shoots there are always other barren shoots that are essentially primary growth for the following year. Of course, this barren growth is variable as to length but, as normally grown with little pruning, the trees contain a very high percentage of extremely short secondary shoots which are neither productive nor long lived.

In one group of 1,633 shoots on which records were taken for four consecutive years, 50.2 per cent of the shoots were 5.0 cm or less in length. Of these short shoots 21.3 per cent blossomed the first year, and of these 29.7 per cent set fruit, so that only 6.3 per cent of the shoots 5.0 cm and less in length were productive the first year. The following year 376 of these shoots were dead. Of the remainder only 4.7 per cent bore fruit. Thus, this type of growth is not only highly non-productive but also suffers a heavy mortality.

Of the shoots above 5.0 cm in length, 69.6 per cent produced bloom the first year. The smallest production in this group was on shoots from 5.1 to 10.0 cm in length of which 44.5 per cent blossomed. Those shoots above 15 cm in length practically all bore bloom, and 93.1 per cent produced fruit. The mortality of shoots was much less in the more vigorous growths, for of 813 shoots over 5.0 cm in length, only 128 died within a year and of these 78 were in the group from 5.1 to 10.0 cm.

The short shoots usually bear a large number of small buds $\frac{1}{4}$ to $\frac{1}{3}$ the normal size. When these buds set clusters of fruit the mortality of the clusters is unusually high. Two hundred eighty-eight such buds set 47 clusters but 25 of the clusters died before maturity so that only 7.6 per cent of the buds produced nuts.

These data indicate that in the naturally grown or unpruned filbert tree a great proportion of the new shoot growth made each year is not only unproductive but relatively short lived. Similar data have been obtained from other groups of filbert trees. These data are also borne out by the rapidity with which the inner part of every filbert tree becomes filled with a mass of fine dead shoots and short weak growth.

Commercial grades of nuts are based primarily on size. There is no lowering of grade on account of lack of color or quality. The filberts are

divided into definite sizes and these sizes are the recognized grades with the stipulation that 90 per cent of the nuts in all grades must contain plump kernels. Since the growers' profit is greatly affected by the quantity of large sized nuts produced per acre, the effect of shoot growth on the size or weight of nuts produced is important.

The relationship between the length of the primary shoots was not directly reflected in the weight of the nuts. Short primary shoots invariably produce short secondary ones, and long primary shoots produce both short and long secondary shoots. The current barren shoots are potentially the primary bearing wood for the following year. Thus, long primary shoots are most desired since they furnish greater potential bearing surface.

It has been thought that when several nuts are borne in a cluster, the weight of the individual nuts is so reduced that little gain in yield is obtained from the larger number. That the weight of the individual nuts is considerably influenced by the number of nuts borne in a cluster is shown by the data in Table I. In obtaining these data the nuts were grouped according to the number of nuts in the cluster without regard to position or length of secondary growth. This lot was harvested so as to obtain equal numbers of nuts from the various types of clusters rather than equal numbers of clusters.

TABLE I—RELATION OF NUMBER OF FILBERTS IN A CLUSTER TO THE AVERAGE WEIGHT PER NUT

Number of Nuts in a Cluster	Average Weight per Nut (Grams)
1	3.07
2	2.99
3	2.81
4	2.87
5	2.47
6	2.40
7	1.99

In the commercial orchard there is considerable variation in the size of the nuts produced on a tree. One of the purposes of this study was to find where nuts of different sizes originated and what factors controlled not only the weight of the individual nut but the total tonnage of the orchard.

In harvesting the nuts for this work the filberts were segregated according to the number of nuts in the cluster and the length of the secondary shoot on which the fruits were borne. The crop was picked clean from the tip of the limbs to the base of the same limbs and from several trees. In the data given in Table II, only filled nuts are considered. At harvest time nuts that are borne singly are almost 100 per cent filled. In clusters of more than one nut, a blank nut may be retained until harvest. Therefore, more blank nuts would be included in collections from clusters of several nuts than from singles.

In Table II are included data for 3,046 nuts, collected from one group of trees 14 years old. These data show that nuts borne singly are much heavier than those borne in clusters of five or six nuts. The average

TABLE II—RELATION OF THE AVERAGE WEIGHT OF THE INDIVIDUAL NUT TO LENGTH OF SECONDARY GROWTH AND TO THE NUMBER OF FILBERTS IN A CLUSTER

Length of Shoot (Cm)	Number of Nuts in a Cluster					
	1 (Grams)	2 (Grams)	3 (Grams)	4 (Grams)	5 (Grams)	6 (Grams)
0- 2.5	3.06	2.85	1.87	—	—	—
2.6- 5.0	3.61	3.38	3.10	3.20	2.70	—
5.1- 7.5	3.76	3.55	3.35	3.20	3.07	2.54
7.6-10.0	4.24	3.63	3.42	3.37	3.37	3.08
10.1-12.5	4.36	3.87	3.70	3.59	3.55	3.40

weight of individual nuts in No. 1 or large sized grade as commercially packed is 3.48 grams. None of the nuts produced by shoots 0 to 2.5 cm in length were of sufficient weight to be first grade. Only the nuts borne singly on shoots 2.6 to 5.0 cm in length were heavy enough to be of first grade. However, it should be pointed out that the total weight of fruit produced is greater when several nuts are borne in a cluster.

One shoot 10.1 to 12.5 cm long bearing five nuts in a cluster, each of which is heavy enough for the large sized grade, produces as much total weight of fruit as four shoots of the same length bearing single nuts. It will be noted that an increase in the length of the secondary growth has a greater influence on increasing the individual size or weight of nut produced than does decreasing the number of nuts in a cluster.

It is still more significant to consider the proportion of long and short shoots bearing single nuts as compared to those bearing several nuts to a cluster. In Table III is given the frequency distribution according to the length of shoot and the number of nuts borne in a cluster of the 3,046 nuts used in Table II. These data show that 20 per cent of the nuts were borne singly on the shortest shoots, while on the longest shoots only 2.2 per cent of the nuts were borne singly.

TABLE III—FREQUENCY DISTRIBUTION OF THE NUMBER OF FILBERTS HARVESTED IN RELATION TO NUMBER IN CLUSTER AND TO THE LENGTH OF SECONDARY SHOOT PRODUCING THEM

Length of Shoot (Cm)	Number of Nuts in Cluster					
	1	2	3	4	5	6
0- 2.5	5	13	7	—	—	—
2.6- 5.0	58	215	166	54	13	—
5.1- 7.5	66	360	370	155	18	15
7.6-10.0	30	187	421	199	84	16
10.1-12.5	13	82	212	168	91	28

The longer primary shoots produce more buds that set a higher percentage of clusters of fruit than do short shoots. The longer secondary shoots bear the larger nuts and more of them in a cluster, which results in an increased total weight per shoot. Theoretically, tree growth could become so vigorous and vegetative that it would be unfruitful but no such instance has been observed. The most vigorous

trees in comparison with slower growing ones have been equally productive when young and more so when mature.

The foregoing data in Tables I to III were taken from nuts produced in one orchard of uniform sized trees. Data obtained from nuts from other orchards showed a similar relation between the number of nuts in the cluster and the length of the shoot on which they were borne. But the actual weights of nuts will vary under different orchard conditions. For instance it is seen from Table IV that a certain length of shoot and number of nuts in the cluster does not necessarily give the same average weight of nut in two orchards. The older orchard produced heavier nuts per unit of shoot length than did the younger orchard. The trees in the younger orchard were at least 40 per cent larger than in the older ones and its yield per acre was 1,400 pounds in comparison with 750 pounds per acre for the 12-year old orchard.

TABLE IV—AVERAGE WEIGHT PER NUT ON SHOOTS 5.1 TO 7.5 CM. IN LENGTH IN TWO ORCHARDS

	10-Year-Old Orchard (Grams)	12-Year-Old Orchard (Grams)
1 nut to cluster	3.41	4.06
2 nuts to cluster	3.11	3.78
3 nuts to cluster	3.09	3.73
4 nuts to cluster	3.01	3.36
5 nuts to cluster	2.94	3.23

The data given in Table IV might indicate that the slow growing small tree was producing a crop of heavier nuts. In fact the younger trees were producing just as many heavy nuts as did the older trees but on the longer shoots, while practically none of the longer shoots were to be found in the older trees. As a general thing, as the trees become older or less vigorous, the average size of the individual nuts tends to become smaller. But in comparing the shoot growth on young trees and older trees it is evident that the decrease in the length of shoot on the old tree is not followed by a comparable decrease in weight of nuts.

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The Specific Gravity as Related to Kernel Development in the Pecan Nut

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ABSTRACT

PRESENT methods of grading pecan nuts do not take into account the degree of filling by any definite criterion. The use of the percentage of kernel has been advocated but due to differences in the varietal thickness of shell is not considered practical. Sitton (1) stated that the percentage of kernel was not a dependable index to the degree of filling, since poorly filled nuts may also have light shells. He reported specific gravity to be a more reliable index. With the object of securing more information on the relation of specific gravity to the degree of kernel development the present investigations were carried out.

The volume, specific gravity, percentage of kernel, weight of kernel per cc volume of whole nut, and weight of shell per cc volume of whole nut of field run nuts of five different varieties were determined.

Thor and Smith (2) stated that the development of the shell is practically complete at the time filling of the nuts begins. This is borne out by the present study. As the specific gravity of the nuts increased the weight of the shell per cc of nut volume increased relatively little, and this weight increase came largely in nuts with a specific gravity above 0.70. Therefore, any increase in specific gravity over that of the empty shell might for practical purposes be said to be due to increase in the kernel weight, except for the variation in the heaviest nuts. However, with the small increase in shell weight and the relatively smaller increase in kernel weight per cc nut volume in the better filled nuts, the ratio of kernel weight to weight of the whole nut, or percentage kernel, did not indicate the degree of filling of such nuts as nearly in true proportion as did the specific gravity. The weight of kernel per cc of nut volume, or the degree of filling, was very closely correlated with the specific gravity in all cases.

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Notes on the Effects of Soil Management on the Growth in Diameter of Pecan Nuts

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THE pecan in the Yuma Valley in Arizona is grown only under irrigation. Differences in soil moisture as induced by frequency and amount of irrigations is therefore one of the more easily managed conditions by which growth differences may be produced. In previous work when soil moisture differences were maintained the size of the nut was apparently regulated to some extent by the amount and the time water was applied. Such a view is commonly held by pecan growers and others familiar with pecan culture.

The present study was made on Burkett trees planted in 1931 on Mohave loam coarse sand, light texture subsoil phase, located on the University of Arizona, Yuma Valley Experiment Station, Yuma, Arizona. A small number of nuts was produced on these trees in 1935 for the first time.

The terms "feeding practices" and "starvation practices" are used here. "Feeding practices" are those treatments which, taken together, tend to promote growth. They include frequent irrigation, growth of legume cover crops, nitrogen and phosphorus fertilization and little plowing. Starvation practices are those which taken together, tend to retard growth. They include infrequent irrigation, growth of soil robbing cover crops, no fertilization, and plowing to destroy surface feeding roots.

The infrequent irrigations were applied by use of one furrow about 5 feet from the trees on each side of tree row so that smaller amounts were applied at greater time intervals. In all plots water was available to the lower roots from the high underground water table which stood at about 5 feet in the season of 1936. There were light showers of rain in January and February and 0.82 inches on July 18, 1936. None of these were believed to have significant influence.

METHODS

The outline of cultural and irrigation treatments used, together with growth responses follow:

I. Season previous to nut growth measurements, 1935.

Plot 1. Feeding practices

Plot 2. Frequent flood irrigations; *Sesbania macrocarpa* grown June to September; 5 pounds "Ammophos" (16-20) per tree in June. Trees highly vegetative.

Plot 3. Starvation practices

Plot 4. Very infrequent flood irrigations; *Andropogon sorghum* grown June to October. Vegetativeness of trees reduced by midsummer. Autumnal colors appeared before that on plots 1, 2, or 5.

¹This report is a part of a general pecan project being conducted cooperatively by the University of Arizona and the U. S. D. A., Bureau of Plant Industry, under the direction of Dr. A. H. Finch.

Plot 5. Starvation practices

One light irrigation, by use of furrows, in July, 1935; clean cultivation. Vegetativeness reduced below that of plots 1 or 2 but not as much as 3 or 4, because of greater "feeding practices" prior to 1935.

II. Season of nut measurements, 1936.

Plot 1. Feeding practices

Frequent flood irrigations (19 applications); Hubam clover grown November to June. (Harvested in late April to allow a second growth.) *Sesbania macrocarpa* grown July to September; 5 pounds "Ammophos" (16-20) per tree in November, April and August (15 pounds total). Trees highly vegetative, but not such luxuriant growth as in 1935.

Plot 2. Starvation practices

Infrequent furrow irrigations (six applications in one furrow each side of tree row beginning after blossoming). Plowed in March. Vegetativeness of trees about like plot 1 until middle of June, then somewhat reduced.

Plot 3. Starvation practices

Infrequent furrow irrigations (seven applications in one furrow each side of tree row beginning after blossoming); plowed in November and again in March. Moderate vegetativeness of trees until middle of June, then considerable yellowing.

Plot 4. (A) Early season (November to August)

Starvation practices

No irrigations; plowed in November and March.

(B) Late season (August to November)

Feeding practices

Frequent flood irrigations (eight applications beginning just prior to the filling process in the nut); 5 pounds "Ammophos" (16-20) per tree in August.

Trees poorly vegetative. Greater degree of starvation than Plots 1, 2, 3, or 5. Did not increase much in vegetativeness even after irrigations were started.

Plot 5. Starvation practices

No irrigation, clean cultivation, plowed in November and March.

Soil Moisture:—Total soil moisture was determined in the surface foot, the second foot, and the third and fourth foot combined at intervals throughout the 1936 season. Soil samples were taken with a soil tube and dried at 110 degrees C to constant weight. Wilting percentages were determined by growth of sunflowers and by centrifuging. Fig. 1 shows moisture percentages and results of wilting point determinations.

Nitrates and Phosphates in the Soil:—The standard phenoldisulphonic acid method was used for the nitrate determinations. The Deniges (1) colorimetric method of phosphate determination was

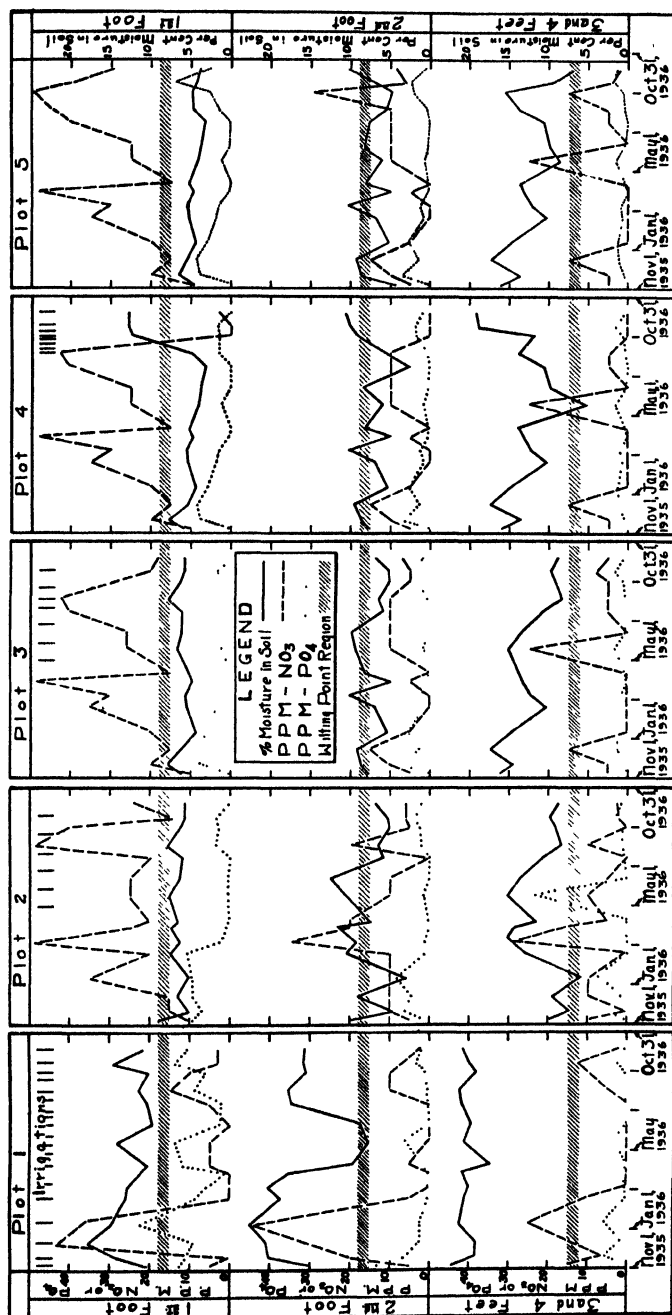


FIG. 1. Showing irrigation, per cent total moisture, wilting percentage, parts per million nitrates and phosphates in the first, second, and third and fourth feet of soil, November 7, 1935, to October 19, 1936. Note time of application and frequency or lack of irrigations as shown by vertical lines at top of chart.

used. Aliquots for each analysis were taken from a one to five extract to which was added activated charcoal to obtain a clear filtrate. Extractions were made for a 20 minute period and CO_2 was bubbled slowly through the extraction flasks which were shaken at regular intervals. Calculations were made to ppm on a dry soil basis.

Measurement of Nuts:—The nuts used for this study were labeled and numbered soon after blossoming. Growth measurements were made on the same nuts at weekly intervals throughout the growing season. A vernier caliper with parallel jaws was slipped back and forth over the nuts to obtain the greatest overall diameter. Some nuts being measured dropped from the trees before complete development. Others at the end of the season proved to be "sticktight". Data on such nuts were discarded in the calculations so that the average diameters obtained were from normal nuts.

PRESENTATION AND DISCUSSION OF DATA

Tree Response:—That differences in growth conditions were produced by variations in cultural treatments was evident by the tree response. "Feeding practices" were observed to give greater shoot growth, both in length and diameter, larger leaves and a deeper green color than did "starvation practices". These induced a lighter green color, smaller leaves, and shorter shoot growth. Current season treatments did not entirely control these responses, presumably because of variable reserve situations in the trees resulting from previous cultural treatments. The effects of these earlier treatments are evidenced in the differences in blossoming in 1936, Table I.

TABLE I—THE EFFECT OF DIFFERENT CULTURAL TREATMENTS IN PREVIOUS YEARS ON THE PERCENTAGE OF PISTILLATE BLOOM PRODUCED IN 1936. NOTE THAT GREATER "STARVATION" IN 1935 DID NOT OVERCOME THE EFFECT OF PREVIOUS YEARS OF "FEEDING"

Plot	Type of Cultural Treatment		Pistillate Bloom, 1936 (Per Cent)
	Previous to 1935	1935	
1	Moderate "feeding"	Moderate "feeding"	42
2	Moderate "feeding"	Moderate "feeding"	25
3	Moderate "feeding"	Moderate "starvation"	3
4	Moderate "feeding"	Moderate "starvation"	15
5	Greater "feeding"	Greater "starvation"	32

Soil Moisture, Nitrates and Phosphates:—Fig. 1 gives the data for the percentage of total moisture and the region of the wilting percentage for each of the three soil depths. The percentages of total moisture in the soils of the five plots show a direct relation to the type of irrigation received and the cover crops grown. The soil moisture in plot 1 was well above the region of wilting percentage except for a short period when the Hubam clover was making a second crop which made heavy demands on the water supply, especially at a depth of 2 feet. The soil of plot 5, without cover crops and without irrigations, had a

moisture supply practically the same as plots 2, 3 and 4. The soil moisture in these four plots was below the region of the wilting percentage in the 1-foot horizon; in the region of the wilting percentage in the 2-foot horizon and generally above the region of the wilting percentage in the 3- and 4-foot horizons. The larger cover crop on plot 4 made greater demands on the soil moisture as indicated by the drop in percentage of moisture during May in the 3- and 4-foot horizons. However, the percentage of moisture was raised considerably in all three horizons of plot 4 when irrigations were made in August just prior to the beginning of the filling process in the nuts.

The soil nitrates in plot 1, Fig. 1, were relatively high in the early winter months and comparatively low for the remainder of the season. From the appearance of the trees it did not seem that there was any lack of nitrogen to meet growth demands. Soil nitrates in plots 2, 3, 4 and 5 were about the same and in all cases much higher in the surface foot than in the deeper horizons, especially compared with plot 1.

The phosphates in plot 1, Fig. 1, ranged fairly high (from 2 to 23 ppm) in the first foot as a result of the application of the "Ammophos" (16-20). In plots 2, 3, 4 and 5 the phosphates in the first foot varied

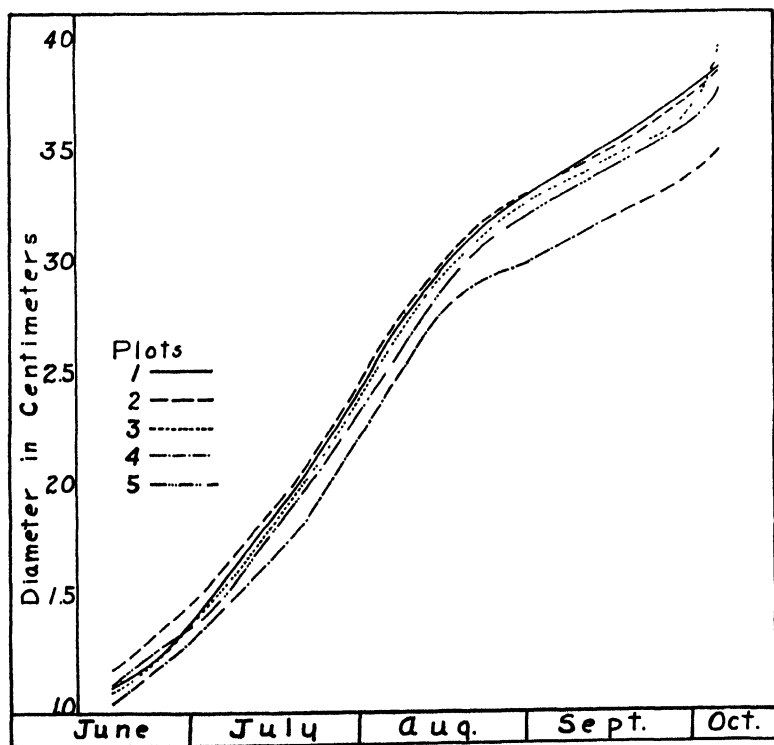


FIG. 2. Greatest diameter averages of nuts measured at weekly intervals from early stages of growth to time of shuck dehiscence. June to October, 1936.

between 0 and 10 ppm for the most part. In all five plots the concentration of PO_4 was slightly less in the second foot than in the first foot, but greater than in the third and fourth foot horizon.

Growth in Diameter of Nuts.—Data for the average greatest diameter of the nuts for each of the five plots are given in Fig. 2. The nuts were measured at weekly intervals from mid-June to early October when the shucks began to crack open. Pistillate bloom appeared first in plot 2 on April 7. The other plots were from 4 to 8 days later in blooming. The trees in all plots were in bloom on April 15. Pollination took place both before and after this date. According to Woodroof (2), fertilization occurs about 5 weeks after pollination, so for the 1936 season it was approximately May 20 in the plots under observation.

The data for the average diameter of the nuts from all five plots are very similar, indicating that no outstanding growth differences were produced by the different cultural treatments even though some tendencies are discernible. The general configuration of the curves is very similar to that found for tomatoes by Gustafson (3). Other workers (4, 5) give growth curves for peaches which suggest a slower rate of increase in diameter during the early development and then a period of rapid increase.

On June 16 the nuts on the trees in plot 2 had the greatest diameter which would indicate either a more rapid rate or earlier growth. This advantage in size of the nuts on plot 2 was maintained until the last of August after the filling process had begun when it was overtaken by plot 1. On June 16 the nuts on plot 5 were smaller than those on plot 2 but larger than those of plots 1, 3 or 4. On July 1 the nuts on plot 5 were smaller than those on plots 1, 2, or 3, but still larger than those of plot 4. The nuts on plot 4 were the smallest on any of the plots at the beginning of the season and remained so to harvest as a result of the cultural treatment designed to starve the trees.

Finch and Crane (6) observed that the early rate of growth had a definite relation to the ultimate size of the nuts. This observation seems to be supported by the data for the nuts on plot 2 which were the largest and those on plot 4 which were the smallest at the beginning of the season and which maintained their relative size to harvest. However, an opposite relation in the growth of the nuts on plots 1 and 5 was found. The nuts on plot 1 started growth in diameter slowly and those on plot 5 started rapidly, but later their growth rate changed. This may be explained by the fact that the trees of plot 1 were highly vegetative in the past, and probably low in carbohydrate reserves and therefore growth was more dependent upon current elaboration of foods. When food became available with the slowing down of shoot growth in early summer, nut growth increased. The trees in plot 5, which had been highly vegetative prior to the "starvation practices" in 1935 (Table I), had sufficient carbohydrate reserves for a relatively rapid growth in 1936, but with continued "starvation practices" nitrogen may have become limited, causing the reduced rate of growth.

Between about July 1 and August 15 the rate of growth of the nuts was about the same for all plots, but after the beginning of the filling process, as evidenced by the presence of a gel layer in some nuts, the

rate of growth was slower. Before August 30 the shells of the nuts had begun to harden. However, growth in diameter of the nuts of all plots continued until just prior to harvest when measurements were discontinued. It seems reasonable to raise some doubt as to further growth in diameter of the nuts after the process of shell hardening is under way. It would seem probable that this slower rate of growth was the result of a thickening of shucks and not to a growth in diameter of the nuts themselves.

The data for plots 3, 4 and 5 again show the effects of more severe "starvation practices" by the sudden rise in the curves (Fig. 2) just before the final measurements were made which probably was due to changes in the shucks caused by their loosening from the nuts just before cracking open. The nuts on plots 1 and 2 had not yet reached a comparable stage of maturity on this date, probably because the trees were more vegetative.

It is impossible to draw valid conclusions from the data thus far obtained. One fact, however, appears to be indicated, namely, that soil moisture alone does not govern the growth in diameter of pecan nuts.

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The Use of Ethylene to Improve Pecan Harvesting¹

By A. H. FINCH, *University of Arizona, Tucson, Ariz.*

FAILURE of pecan nuts to mature satisfactorily has been a serious problem in certain of the fertile valleys of the irrigated Southwest which are characterized by favorable growing conditions and high fall temperatures. Imperfect maturity is manifested by a faulty or delayed separation of the shuck from the shell and subsequent dehiscence of the shuck. This delays harvest, increases the cost of gathering and preparing the nuts for market, and contributes to the pre-harvest germination of the nut through providing a continuous supply of moisture in close contact with the shell over an extended period. A further commercial defect and manifestation of immaturity is the light color of the shells of some nuts. Shells of well matured nuts are a typical brown.

These imperfections have been more completely described in a recent publication (2) in which a relation of maturity and filling of the nut to tree vegetativeness was reported. By controlling vegetativeness a considerable control over nut filling and maturity may be had. There are, however, certain climatic difficulties which prevent the complete and satisfactory elimination of the maturity problems by cultural methods alone. Filling of the nuts appears to respond quite satisfactorily to cultural manipulations.

Preliminary studies of the effect of ethylene upon pecan maturity were made during the 1935 harvest and have been conducted more extensively in the 1936 season. It has been found that ethylene is effective in causing the shucks of pecan nuts to loosen from the shells, and the shucks when so loosened dehisce normally. Ethylene gas applied for a 48 hour period during the middle of September to a tree enclosed under a fumigating tent caused normal shuck dehiscence and ripening of the nuts. (Fig. 1, A.) This was more than 30 days prior to the usual harvest date. Before treatment the nuts gave no evidence of approaching maturity. They were, of course, incompletely filled.

At intervals from the middle of September throughout the period of harvest, nuts of many varieties were picked, placed in reasonably air tight containers and surrounded with an atmosphere containing ethylene of an approximate concentration of 1-1,000. Without exception the shucks were loosened by the ethylene and could readily be removed from the nuts after 24 to 48 hours. It was not possible to maintain constant temperatures in the treatment chambers but by applying artificial heat the temperature in some chambers was maintained as high as 45 degrees C for a period of 12 hours without apparent injurious effect upon the quality of the nut or kernel. Four charges of ethylene were made each 24 hours and complete ventilation provided between successive charges.

The effectiveness of ethylene in pecan harvesting appears to be limited to improving the separation of the shuck from the shell for it has had no effect upon the coloring of the shell. Coloring of the shell

¹This paper is a joint contribution of the Arizona Agr. Exp. Sta. and the Division of Fruit and Vegetable Crops of the Bureau of Plant Industry, U. S. Dept. of Agriculture.

seems to develop from contact with the shuck tissues during the process of drying. By adapting the harvesting practices to permit of drying the nut in the shuck after treatment with ethylene, normal shell coloring is produced.

In Arizona, as elsewhere, the custom has been to wait for the opening of the shucks to begin pecan harvest. Under the high temperature conditions of this district a completely satisfactory condition of shuck opening is seldom attained in commercial orchards of some varieties. As soon as the shucks have opened sufficiently to make it at all possible, the nuts are thrashed from the trees. The shucks which in a considerable proportion of the nuts still adhere are immediately removed, usually with considerable labor and expense. The shell on the nuts to which the shucks have adhered very tightly is poorly colored. After removing the shucks the nuts are allowed to dry until ready for market.

By the use of ethylene certain improvements in the method of harvesting seem possible. Instead of waiting for the shucks to open before beginning harvest, the nuts may be gathered as soon as maximum quality of the kernel is attained. This will necessitate picking rather than thrashing the nuts from the tree, allowing them to drop onto sheets spread beneath the trees. By this method of harvesting the nuts as soon as picked would be treated with ethylene for a period of 24 to 48 hours, after which they would be dried with the shucks still on. Drying in contact with the shucks provides for normal coloration of the shell (Fig. 1, D). In the 1936 experimental work, the nuts were dried by placing them in the sun. It is presumed that artificial drying would be as effective. In drying, the shell becomes normally colored,

TABLE I—PRELIMINARY DATA ON MATURITY OF HALBERT NUTS FROM TREES OF INTERMEDIATE TO HIGH VEGETATIVENESS, YUMA, ARIZONA

Date	Shuck Separation	Pre-harvest Germination (Per Cent)	Shell Color	Specific Gravity of Nuts	Kernel*
1936					
Oct. 9	30 per cent opening along sutures. Basal portion of shuck still adhering.	3.4	Normal to Light	.75	Slightly lacking in oil but good flavor and quality.
Oct. 15	50 per cent opening along sutures. Shucks loosening at base.	15.9	Normal	.78	Kernels seem to have full quality and flavor.
Oct. 21.	Slow advancement in shuck separation and opening	29.6	Normal	.79	Kernels seem to have full quality and flavor.
Nov. 2.	Continued slow advancement.	35.7	Normal	.79	Kernels seem to have full quality and flavor.

*These data are based upon examination of the kernels after all nuts had been cracked. Chemical analyses are now in progress.

the shucks open well (Fig. 1, C) and can be readily removed. The nuts are at once ready for grading and marketing. With ordinary sun drying the entire process of picking, gasing, drying and grading appears to require not more than 10 to 12 days and this because of the earlier possible picking date should provide for considerably earlier marketing than has been the rule.

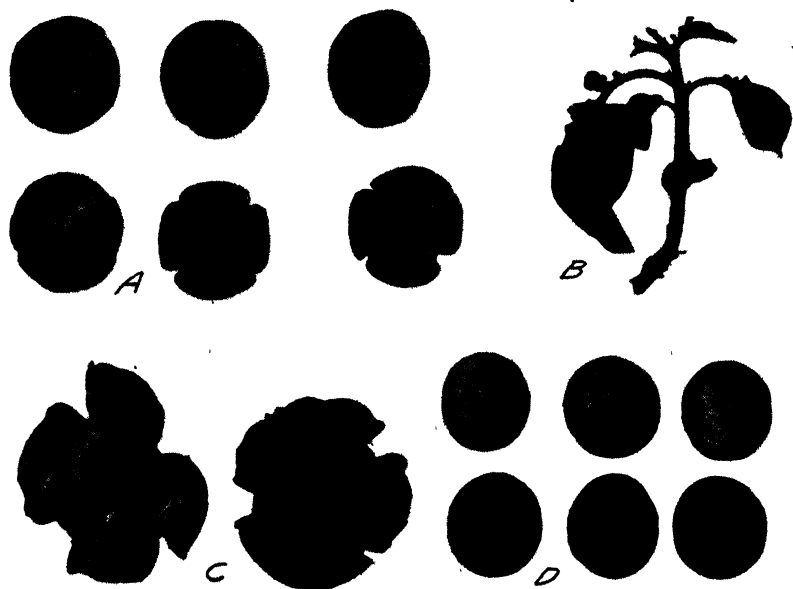


FIG. 1. A, Bottom row, showing normal opening of shucks following exposure to ethylene during mid-September. Photo taken eight days after treatment. Top row, nuts from an adjacent untreated tree. B, Epinasty of a young potato plant after being confined with pecan shuck tissue for 36 hours. C, Showing condition of shuck opening in Burkett following treatment with ethylene gas and subsequent drying. D, Coloring of shell following: (top) drying after shuck removal, and (bottom) drying in the shuck. Ethylene treatment improves the color of the shell chiefly in that drying the nut with the shuck on becomes practical.

The present indications are that in this region of high fall temperatures, optimum quality of the kernel may be attained before the shucks open well. It is during this period that much of the pre-harvest germination of nuts occurs. By picking the nuts as soon as optimum kernel quality is attained it is believed that pre-harvest germination can be largely prevented. The preliminary data of Table I suggests how this may be accomplished on Halbert nuts from a commercial orchard in the Yuma Valley. Pre-harvest germination is frequently extensive in this variety.

Apparently by the middle of October or shortly thereafter, the kernels had attained their full commercial quality and very little was

gained either in quality of nut or in ease of harvest by allowing them to remain upon the tree. By so doing a substantial loss was incurred through an increase in pre-harvest germination. On October 15 germinated nuts had no growth of the hypocotyl outside of the shell and were marketable as a lower grade. With the growth of the hypocotyl as the season advanced the germinated nuts lost any value they may have had.

With the use of ethylene to loosen pecan shucks, the shuck opening itself is no longer a satisfactory index of when harvesting should begin. With the picking date dependent upon the attainment of optimum kernel quality, it is necessary to know when this quality is attained and to have an index of it which can be used by the grower. Thor and Smith (3), found that if harvest occurs too early the quality of pecans is sacrificed. Similarly, in Arizona, if harvest of some varieties is delayed losses through pre-harvest germination are incurred. It is planned that further studies will be centered upon gaining an accurate index of kernel quality.

The effectiveness of ethylene in causing pecan shucks to loosen from the shells at once raises the question of possible ethylene-like emanations from pecan tissues. One test for emanations causing leaf epinasty was made. For this, a method described by Denny (1) was used. This consisted of confining a young potato plant under a bell jar with pecan shucks. In this one case a typical epinasty of the plant (Fig. 1, B) followed after about 36 hours.

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Seasonal Changes in the Composition of Pecan Roots

By J. G. WAUGH and C. L. SMITH, *U. S. Department of Agriculture, Austin, Tex.*

ABSTRACT

This material will be published in full in the *Journal of Agricultural Research*.

THE importance of food reserves in the growth and fruiting performance of pecan trees and the function of the roots in the storage of these reserves and absorption of soil nutrients has been emphasized. In view of their importance it seemed desirable to obtain some information on the proportionate accumulation of food reserves in the roots of pecan trees during the various seasons and the effect of the nut crop on their accumulation. Since the pecan is frequently an alternate bearer, healthy native trees near Austin, Texas, in an alternate bearing condition were used. Composite samples were taken from the lateral roots of comparable groups of trees in rotation during an "off", "on" and "off" year, at intervals of 2 weeks to approximately 1 month. These root samples were analyzed for dry matter, reducing and non-reducing sugars, starch, hemicellulose and total nitrogen.

Analysis of the data indicates that starch and hemicellulose are the principal reserves. Starch showed a greater response to the needs of the tree and had a greater range of variation than the hemicellulose. Both constituents reached their maximum concentrations toward the close of the initial "off" year and decreased during the following "on" year. The starch decreased rapidly during the period of vegetative growth of the tree, then increased during the period of shuck and shell formation and decreased again during the period of nut filling and ripening. The hemicellulose decreased more gradually to a minimum value at nut drop. Toward the end of the following "off" year, hemicellulose had regained its former "off" year value, but the starch remained low. The cause of this may be in the weather, the initial "off" year being very dry and the succeeding "on" and "off" years having plenty of moisture. Further determinations are in progress to learn if the starch will eventually increase.

Fluctuations of the reducing and non-reducing sugars seem to indicate that they serve more as labile or translocatable forms of carbohydrates and less as storage forms. The reducing sugar was at all times very low, never exceeding 1 per cent on a dry weight basis. The non-reducing sugar attained its maximum concentration toward the close of the initial "off" year and decreased during the vegetative and fruiting periods of the trees. Roughly the variation is similar to that of starch, though on a much smaller scale.

The total nitrogen increased up to the beginning of the vegetative period of the "on" year, and decreased during this period, indicating a demand for nitrogen. During nut development and filling, nitrogen increased. Toward the close of the succeeding "off" year, its value was nearly the same as its former "off" year value.

The dry matter content was high at the close of the initial "off" year, after which it decreased to a minimum at the beginning of the

vegetative period, then increased slightly and remained fairly constant to the time of nut drop. Toward the close of the succeeding "off" year the percentage dry matter was considerably lower than for the corresponding date of the initial "off" year. There is an indication that this may in part be due to the initial "off" year being very dry and the succeeding years having plenty of moisture. There seems to be an approximate correspondence between starch and dry matter.

Growth of Citrus Trees

By F. F. HALMA, *University of California, Los Angeles*, and
C. COMPTON, *University of California, Riverside, Calif.*

THE term "growth" as used herein is limited to increase in cross-sectional area of the trunk. This method of recording growth is accurate and reliable on young citrus trees, for the trunk is smooth and practically cylindrical. Growth observations made in this manner have been found useful in the study of water relations (2).

This report deals with the seasonal growth of the Washington Navel orange (a variety of *Citrus sinensis* Osbeck) and the Eureka lemon (a variety of *C. limonia* Osbeck). The orange trees were planted in 1930 in a 10-acre block at Riverside, California. The rootstock is sweet orange (*C. sinensis* Osbeck) and sour orange (*C. aurantium*) in alternate rows. The soil is classed as a Ramona sandy loam. The climate is representative of that in the interior citrus-growing regions of southern California. Maximum summer temperatures range from 107 to 112 degrees F, with higher temperatures being recorded occasionally. Minimum temperatures are generally not lower than 26 degrees F. The annual rainfall is about 10 inches, all of which ordinarily falls between November and March. In 1933 the orchard was divided into 10 plots for an irrigation experiment.

Beginning in 1933 and continuing up to the present, monthly growth measurements were made on 16 to 32 trees in each plot by measuring the circumference in centimeters about 20 centimeters below the first branch. The values were then converted into square centimeters of cross-sectional area.

The lemon trees were measured only during the year 1934. These trees were planted in 1932 in four different commercial orchards at Upland, California. Each plot consists of about 2 acres; half of the trees are budded trees on grapefruit (*Citrus paradisi*, Macf.) rootstock, and the other half are own-rooted, that is, they were propagated by means of stem cuttings. The climate is similar to that in Riverside, but the annual rainfall is about 15 inches. The soil is classed as a Hanford stony, sandy loam. Measurements were made at approximately monthly intervals on 20 trees in each of the four plots.

In Figs. 1 and 2 the monthly growth is plotted as a percentage of the annual growth. This mode of presenting the data is better suited to this discussion than one showing the monthly growth increments.

It will be seen that about 90 per cent of the annual growth observed for the orange trees occurred approximately between May and November, or a period of 6 to 7 months, while for the lemon trees, it occurred between about March to December or a period of about 10 months.

The orange trees in all of the plots behaved alike in this respect showing that the various irrigation practices tested had no effect on the length of the growth period. The growth period of the lemon trees was also practically the same in all four plots, although the cultural treatment varied considerably. The rootstock also must be eliminated as a factor which determines the length of the seasonal growth period since the orange trees on both sweet and sour orange rootstocks, as

well as the lemon trees with and without rootstock, behaved alike. The period of growth should not be confused with growth increment, for in the latter, the rootstock species as well as the available soil-moisture supply are important factors.

Soil temperature appears to be an important factor, if not the limiting one under field conditions in determining the length of the period of

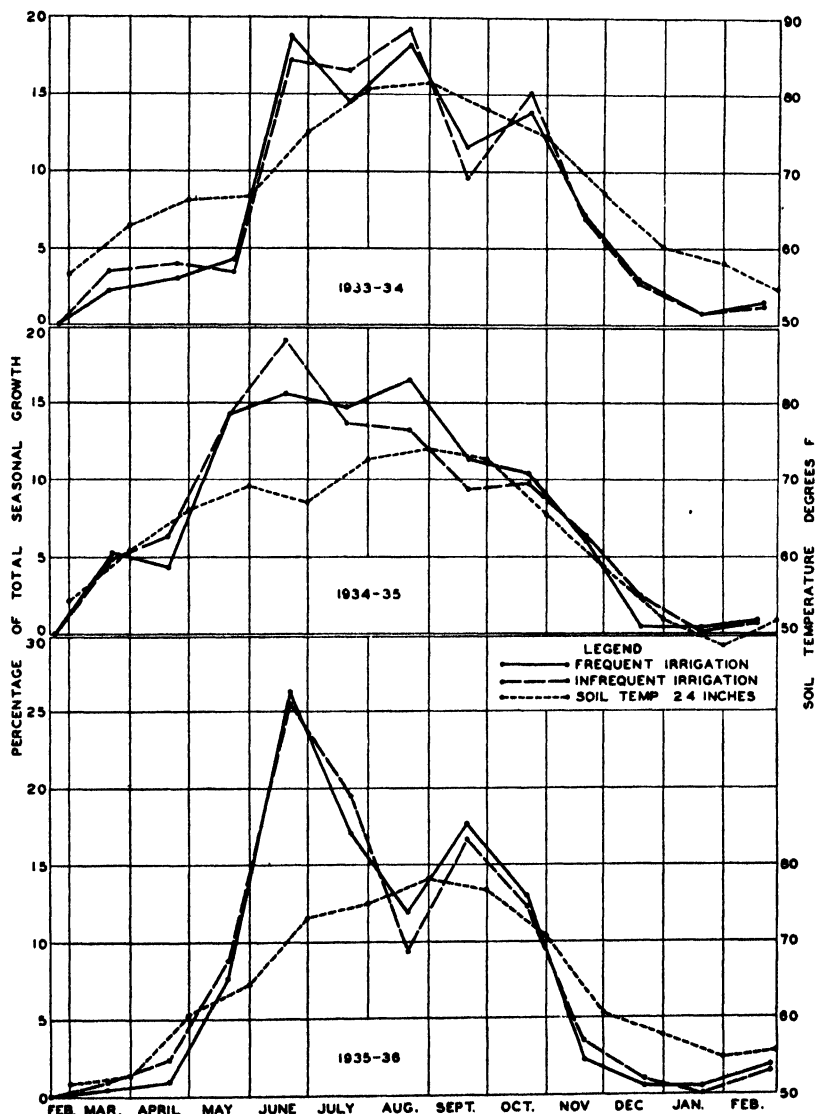


FIG. 1. Monthly growth of Washington Navel orange trees expressed as a per cent of annual growth.

growth. The soil temperatures plotted in Fig. 1 are for a depth of 60 centimeters (24 inches). The relatively inactive period corresponds to a temperature of about 65 degrees F or lower. This minimum would, of course, vary with the depth at which the temperature is read. No continuous records are available for the lemon plots, but readings made at irregular intervals show approximately the same seasonal curve as for the orange plots. This means that the lemon trees are able to grow under a wider range of soil temperatures than the orange trees, an assumption which finds support in the results of a previous investigation (3).

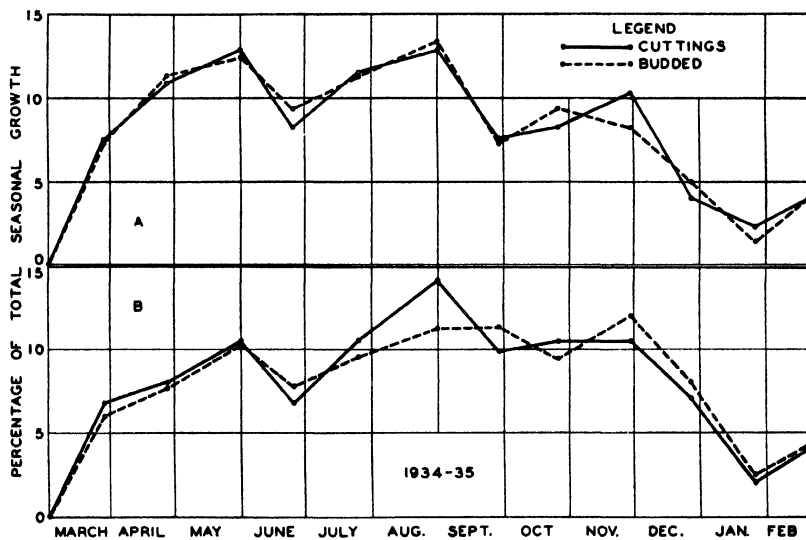


FIG. 2. Monthly growth of Eureka lemon trees expressed as a per cent of annual growth.

Two other previous findings may be mentioned, as they are pertinent to the present discussion. One of them is the relationship between citrus leaf sap concentration and soil temperature (1). The period of high osmotic values of the sap occurred when the soil temperature was relatively low. But the osmotic value curve differs slightly from the growth curve in that the former begins to drop off about February when the trunk is still relatively inactive. Whether this is due to the beginning of the blossoming period has not been determined.

Citrus roots under interior climatic conditions do not regenerate new roots or even produce callus, when pruned during the period of least tree growth (4). This is illustrated in Fig. 3 which is reproduced here from the article cited above. All the interrelationships mentioned suggest that soil temperature is the most important factor, if not the limiting one in the yearly growth of citrus trees under orchard conditions. They further suggest that trunk growth observations furnish the simplest and most reliable index for tree activity as a whole.

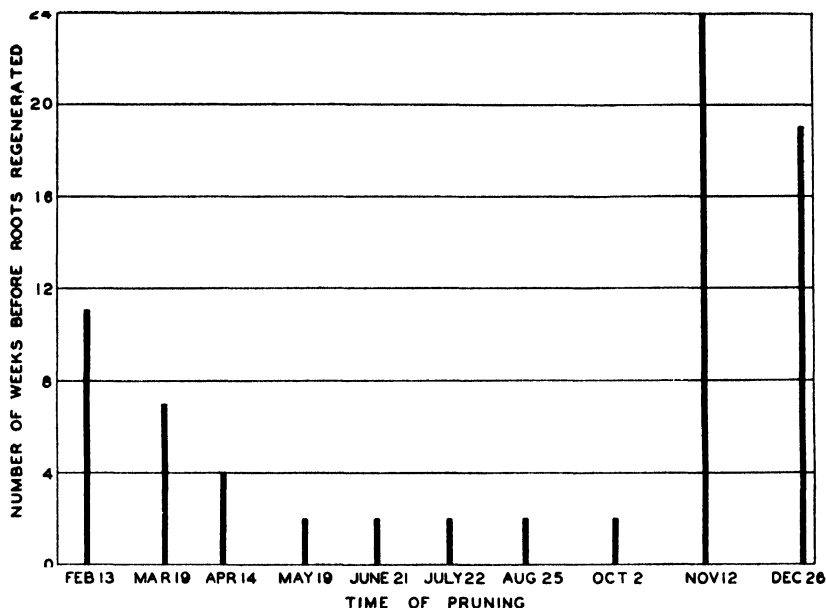


FIG. 3. Time required for pruned orange roots to regenerate new rootlets.

SUMMARY

1. Monthly measurements of the cross-sectional trunk area of the Washington Navel orange tree and the Eureka lemon tree show that under the interior climatic conditions of southern California the most active growing period is 6 or 7 months for the former and 9 to 10 months for the latter.

2. This growth period was not influenced by the rootstock or by soil-moisture conditions.

3. Soil temperature seems to be the most important limiting factor for the growth of citrus under field conditions.

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Total Pectinous Material in the Vegetative Portions of Citrus Trees¹

By A. R. C. HAAS, *University of California Citrus Experiment Station, Riverside, Calif.*

THIS paper records the only data available at present regarding the effect of the time of the year and of the varieties on the content of total pectinous materials of certain combinations of scion and stock. The results make it possible to relate the content of total pectinous materials of the vegetative to the reproductive phases in the growth of citrus.

Estimations were made as calcium pectate in the manner described by Buston (1) except that larger samples were used and that the solutions were centrifuged instead of being filtered. The material consisted of samples of leaves or bark which were rapidly dried below 60 degrees C and finely ground.

Preliminary determinations on a number of leaf and bark samples collected at various times showed (Table I) a relatively high total content of pectinous material. Because of wide variations in the age and size of the trees, soil treatment, and time of collection, a comparison of the individual determinations will not be made.

TABLE I—TOTAL PECTINOUS MATERIAL (AS A PERCENTAGE OF CALCIUM PECTATE) IN THE DRY MATTER OF HEALTHY LEAVES AND TRUNK BARK OF CITRUS SCIONS AND STOCKS

Variety		Material	Calcium Pectate (Per cent)
Scion	Stock		
Valencia orange	Sour orange	Valencia orange leaves	16.98
Sour orange	_____*	Sour orange leaves	16.68
Eureka lemon	_____*	Eureka lemon leaves	14.59
Mexican lime	_____*	Lime leaves	20.15
Sweet orange	Sour orange	Sour orange bark	22.25
Sweet orange	Trifoliolate	Trifoliolate orange bark	24.45
African sour orange	Sour orange	Sour orange bark	26.41
Grapefruit	Sour orange	Sour orange bark	27.13
Lemon	Sour orange	Sour orange bark	28.49
Eustis limequat	Grapefruit	Grapefruit bark (Hall's Silver Cluster)	29.81
Sampson tangelo	Sour orange	Tangelo bark	22.37
Savage citrange	_____*	Citrange bark	24.99
Marmumi kumquat	_____*	Kumquat bark	30.18
Trifoliolate orange	_____*	Trifoliolate orange bark	31.09

*Rootstocks not determined.

In Table II are given data regarding the content of total pectinous material in healthy and mottled leaves collected at approximately the same time from trees grown on sweet orange stocks. No significant differences were found in healthy and mottled leaves and no relation to soil fertilization was apparent. The results in Table II show wide variations in citrus leaves of the same variety.

¹Paper No. 364, University of California Citrus Experiment Station and Graduate School of Tropical Agriculture, Riverside, Calif.

TABLE II—TOTAL PECTINOUS MATERIAL (AS A PERCENTAGE OF CALCIUM PECTATE) IN THE DRY MATTER OF VALENCIA ORANGE

Leaves	Per Cent					
Healthy	12.21	18.62	21.25	16.94	16.87	18.04
Mottled	20.32	16.91	19.06	16.99	16.72	18.35
Healthy	21.85	13.79	20.57	18.50	19.43	11.44
Mottled	17.03	10.22	16.63	14.33	18.71	8.89

In Table III are given the percentages in healthy and mottled leaves and in the bark of the scion and stock of trees grown under uniform soil treatment and cultural conditions in the Plant Pathology plots.² Samples were collected on October 3 and on December 11, 1930. Each scion sample of trunk bark consisted of three strips 1 to 2 inches wide, 3 or more feet in length, cut from each of two or three trees. The strips of bark of the scion varieties were divided into three vertical samples: upper, middle, and lower thirds. The three strips of bark of the stock varieties cut from each of two or three trees were taken to 6 to 10 inches below the level of the soil.

As previously noted, no significant relation was found between the content of total pectinous material and mottling. Healthy leaves from grapefruit trees on sweet as well as on sour stock contained greater percentages in the December than in the October samplings; healthy leaves from lemon trees on these same stocks contained greater percentages in the October than in the December samplings.

Table III shows that the percentages for the bark of the stocks are considerably lower than those for the bark of the scions. Except for grapefruit on sour, the percentages of the scion bark samples collected in October are less than those for the samples collected in December.

In all scion bark samples except lemon on sour, the percentages of the middle third are less than those of the upper or lower thirds. The percentages for the middle third of the bark of lemon scions on sour stock are higher than in the middle third portions of any of the other scion bark samples tested.

In the upper third samples, grapefruit on sweet had the highest percentage; in the middle or lower thirds, lemon on sour and sweet had the highest percentages. The high position of the bark samples of lemon and of grapefruit as regards their content of total pectinous material parallels that of fruits of these species.

The percentages are higher for the sour than for the sweet stocks when the scions in both cases are Eureka lemon. The lowest percentages were those of sweet stock (lemon scion) and sour stock (Navel scion). It is well known that the latter combination of scion and stock is compatible.

The percentages of the total pectinous material in bark samples obtained from various scion and stock combinations³ are given in

²The assistance of Dr. L. J. Klotz in securing the bark samples is gratefully acknowledged.

³These samples were obtained from trees grown by Dr. H. B. Frost to whom grateful acknowledgment is made.

Table IV. The bark samples were taken a few inches above and below the bud unions. It is of interest, therefore, that the percentages for the scion variety in every case are greater than those for the stock variety. Tangelo and grapefruit contain the highest percentages among the scion bark samples.

TABLE IV—TOTAL PECTINOUS MATERIAL (AS A PERCENTAGE OF CALCIUM PECTATE) IN THE DRY MATTER OF THE BARK OF VARIOUS SCIONS ON SOUR ORANGE AND ROUGH LEMON STOCKS. (SAMPLES COLLECTED SEPTEMBER 25, 1935)

Scion	Stock	Calcium Pectate in Bark of Trunk	
		Scion	Stock
Valencia orange.	Sour orange	20.97	18.06
Imperial grapefruit.	Sour orange	26.54	17.67
Lisbon lemon.	Sour orange*	23.49	26.64
Eureka lemon.	Sour orange	21.32	20.74
Valencia orange.	Rough lemon	22.28	20.23
Imperial grapefruit.	Rough lemon	23.59	21.90
Sour orange.	Rough lemon	20.11	—
Tangelo.	Rough lemon	27.71	24.89

*Overgrown by scion.

The percentages for the sour stocks are lower than those for the Rough lemon stocks when Valencia and grapefruit are the scions. When Valencia and grapefruit scions are on sour, the percentages for the stock are the lowest among the results for the stock bark samples. The percentages for the sour stocks that were badly overgrown by lemon scions are the highest among the results for the bark samples of sour stock.

A greater amount of data than these preliminary results afford will be required to appreciate more fully the significance of pectins in citrus. It is essential that attention be given the several forms and the location of the pectinous materials. Variations in the content of pectinous materials in the bark of scions and stocks may be of importance in the severity of certain bark diseases according to the elevation on the tree axis.

SUMMARY

Pectinous materials (determined as calcium pectate) were found to occur in large concentrations in citrus leaves and bark. In the trees sampled the bark of the stock usually contains a lower percentage of total pectinous materials than the bark of the scion. In most cases the percentages in the scion bark samples collected in October are less than those for the samples collected in December. The percentages for the middle third samples of the bark of lemon scions on sour stock are higher than in the middle third portions of any of the other scion bark samples tested. The high content of total pectinous materials in lemon and grapefruit bark samples parallels that of the fruits of these species.

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Loss of Nitrogen Through Abscission of Immature Oranges

By S. H. CAMERON, *University of California, Los Angeles, Calif.*

IN previous contributions (1, 2) the suggestion was made that probably an appreciable quantity of nitrogen is removed from orange trees through the shedding of young fruits. The present paper reports the results of a study to determine the magnitude of these losses.

During the spring and summer of 1935 and 1936 all the young fruits which dropped from two 7-year-old Valencia orange trees in the orchard of the Division of Subtropical Horticulture, University of California, Los Angeles, were caught on sheets spread beneath the trees. The fallen fruits were picked up daily except Sundays and holidays from April 14 to September 12, 1935 and from April 15 to June 21, 1936. Some fruits dropped after the collections ceased; however, the number was insufficient to warrant further collections. The "drops" were counted, dried, ground and analyzed for total nitrogen by the Kjeldahl-Gunning method.

The Valencia orange tends to bear alternately large and small or medium crops. It is a common observation that the heaviest "June drop" occurs in years of heavy bloom. The data obtained during the two seasons of this investigation are in agreement with this observation. The total drop during 1935, a year of heavy bloom, was 20,476 and 15,888 fruits respectively from the two trees and in 1936, a year of light bloom, 835 and 1,097.

In 1936 the two trees yielded 325 and 365 pounds. This crop resulted from the heavy bloom of the spring of 1935 which was followed by the heavy drop previously referred to. The 1937 crop, set during the light bloom period of 1936, will probably not exceed 100 pounds per tree. This suggests that small crops may be due to light bloom rather than to excessive dropping following heavy bloom. Apparently the belief that a heavy "June drop" results in a small crop does not apply to this variety when grown in the coastal belt of southern California.

Characteristically the orange tree blooms throughout a period of several weeks. There is a continuous dropping of pistils and other flower parts during this period. A much heavier drop occurs somewhat later and consists principally of young fruits. Fig. 1 illustrates the nature of the abscission. Two periods of dropping are indicated in contrast to the four waves of shedding reported for the apple by Murneek (3). The periods are quite distinct in the heavy bloom year but are not conspicuous in the light bloom year. Fecundation is probably not an important factor in abscission since this is not necessary for normal development of the citrus fruit.

That the drop is caused by an insufficient supply of nitrogen has been suggested by both growers and investigators. In the year of heavy bloom 54.87 and 49.71 grams of nitrogen were removed from the two trees as a result of the shedding of immature fruits. In the year of light bloom the corresponding figures were 2.17 and 3.12

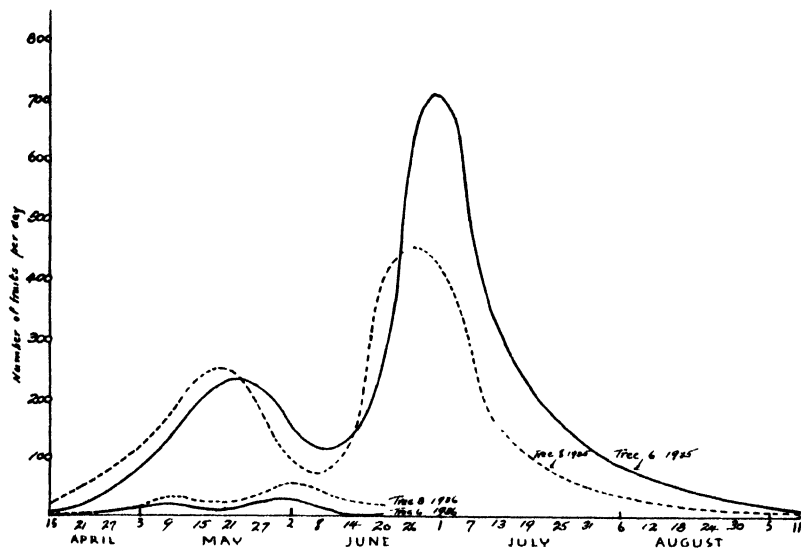


FIG. 1. Abscission of immature Valencia oranges.

grams. The data are not adequate to justify the definite conclusion that the drop is due to or responsible for a nitrogen deficiency in the tree. That such may be the case, however, is suggested by the

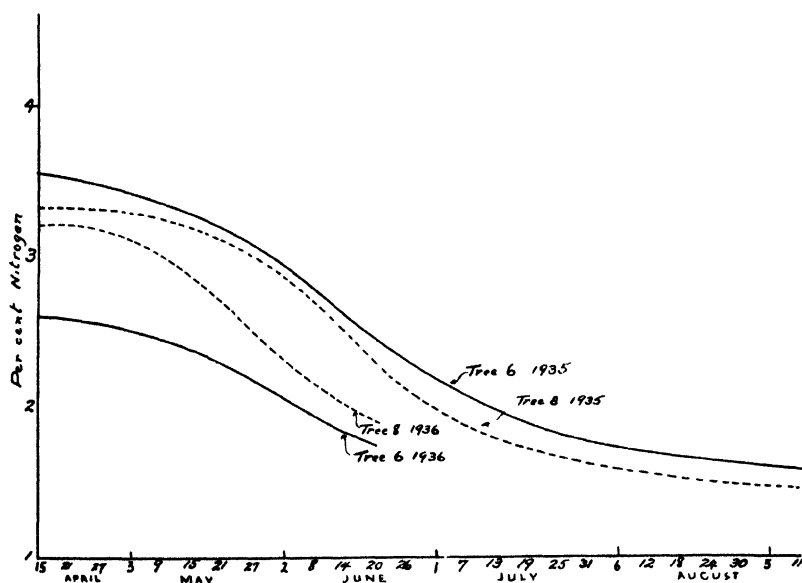


FIG. 2. Nitrogen content of abscised fruits of Valencia orange expressed as per cent of dry weight.

data presented in Table I which shows a decrease in nitrogen content in fruits of equal dry weight as the season advanced.

TABLE I—NITROGEN CONTENT OF ABCISSSED FRUITS OF EQUAL DRY WEIGHT (0.07 GRAMS) COLLECTED ON DIFFERENT DATES

Date	Tree 6 Nitrogen Content (Mgs)	Date	Tree 8 Nitrogen Content (Mgs)
April 16	2.30	April 16	2.21
May 5	2.30	May 7	2.19
May 16	2.28	May 14	2.21
May 24	2.19	May 23	2.16
May 31	2.07	May 31	2.09
June 6	1.90	June 6	1.91
June 18	1.69		

That the dry weight increased more rapidly than the nitrogen content is shown in Fig. 2. When calculated as a percentage of the dry weight a steady decline in nitrogen content is indicated. This corresponds with previous observations made on fruit picked from the tree (2).

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Water Deficit in Citrus

By C. COMPTON, *University of California, Riverside, Calif.*

EXPERIMENTS with citrus begun on the tract of the Division of Irrigation Investigations and Practice at the Citrus Experiment Station in 1933 as reported by Halma (1, 2), have shown that the "relative saturation deficit"¹ has an inverse relationship to soil moisture, and that when the R.S.D. is allowed to reach a high value, reduced tree growth as a whole is the result. This report presents data on the diurnal changes in the R.S.D. during 1936 in a 6-year-old Washington Navel orange (a variety of *Citrus sinensis* Osbeck) grove at the Citrus Experiment Station, Riverside, California. The trees used in this experiment are on sweet orange (*C. sinensis* Osbeck) rootstock. They are planted 20 feet apart in the row with the rows 24 feet apart. Rows are 10 trees long.

Two irrigation treatments were used, frequent and infrequent. In the frequently irrigated plots, hereafter designated as treatment A, the R.S.D. was maintained at a low value. Fruit growth was kept at a maximum. In the infrequently irrigated plots, hereafter designated as treatment B, the R.S.D. was allowed to reach a definite peak before applying water. The fruit ceased increasing in size before water was applied. Two plots in each treatment were available.

Samples were collected at 2-hour intervals from July 15 to 20 and August 22 to 25, at 6:00 a.m., 12 noon, and 6:00 p.m. from August 26 to 31, and at 4-hour intervals for 48 hours beginning at 8:00 p.m. November 7. Eight trees, well surrounded with guard trees, were used in each plot. One leaf taken from the shady side of each of these trees constituted a sample. Irrigation was applied in nine straight furrows on each side of the tree row, thus wetting about 90 per cent of the total soil area. The data were consistent for duplicate plots, as is shown in Fig. 3. Data were obtained from only one plot in each treatment for the period July 15 to 20.

Treatment A was irrigated July 10 and treatment B on June 9, 5 and 36 days, respectively, before leaf sampling started on July 15. Soil moisture was above the permanent wilting percentage, hereafter referred to as the P.W.P., in all the irrigated soil (excluding the soil mulch) on both plots at this time, but had dropped to the P.W.P. in the top foot in treatment B by July 23. A portion of the soil moisture data is presented in Fig. 1.

Highest air temperatures from July 15 to 19 inclusive were 114, 112, 116, 105, and 99 degrees F. Lowest relative humidities for the same period were 11, 19, 21, 38, and 35 per cent. During most of the time there was little difference in the R.S.D. either from one day to the next or between treatments A and B. The minimum R.S.D. generally occurred about 4:00 a.m., the maximum between 12:00 noon and 2:00

¹The "relative saturation deficit" in citrus leaves which is hereafter referred to as the R.S.D. may be expressed conveniently by means of the following formula:

$$\text{R. S. D.} = \left(\frac{\text{Weight at Saturation} - \text{Weight when picked}}{\text{Weight at Saturation}} \right) \times 100.$$

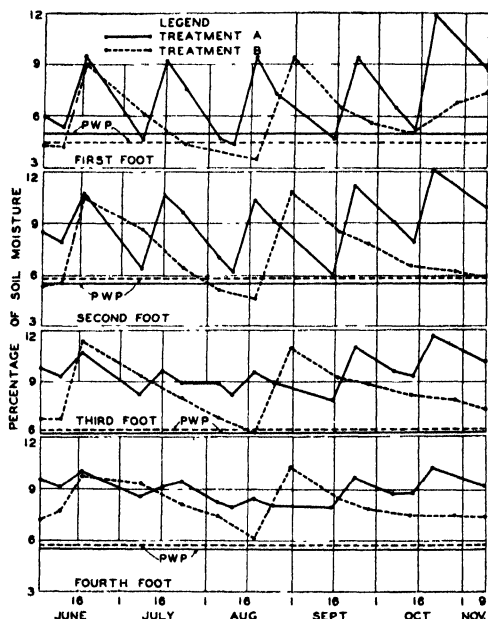


FIG. 1. Soil-moisture conditions in the orange grove, 1936. One and one-half inches of rain fell on October 30 and 31, wetting the top foot of soil.

in treatment B had been showing slight wilt in the morning for about 2 weeks, yet it was not until August 24 that the fruit stopped increasing in size, as is shown in Fig. 3.

Irrigation water was applied August 24 on treatment B, starting at

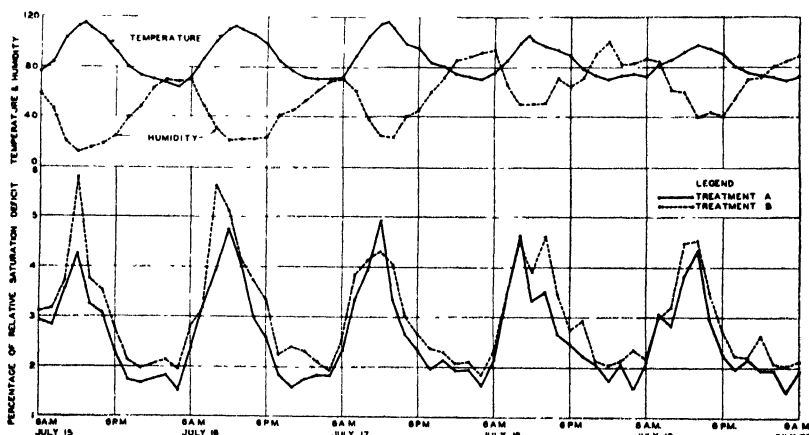


FIG. 2. Relative saturation deficit of Navel orange leaves during a period of high daily temperature.

p.m. The daily range as shown in Fig. 2, in treatment A was from 1.5 to 5.0 per cent; in treatment B, 2.0 to 5.8 per cent. The trees in both plots were able to obtain soil moisture to approximately the same degree even though the moisture content of the top foot of soil in treatment B was approaching the P.W.P.

During the second period of sampling which started August 22 the weather was moderate but soil moisture in treatment B was at about the P.W.P. in the first 4 feet of soil, as is shown in Fig. 1. In addition to the leaf samples, 10 fruits were measured on each plot with a circumference gage accurate to plus or minus 0.5 mm. The trees

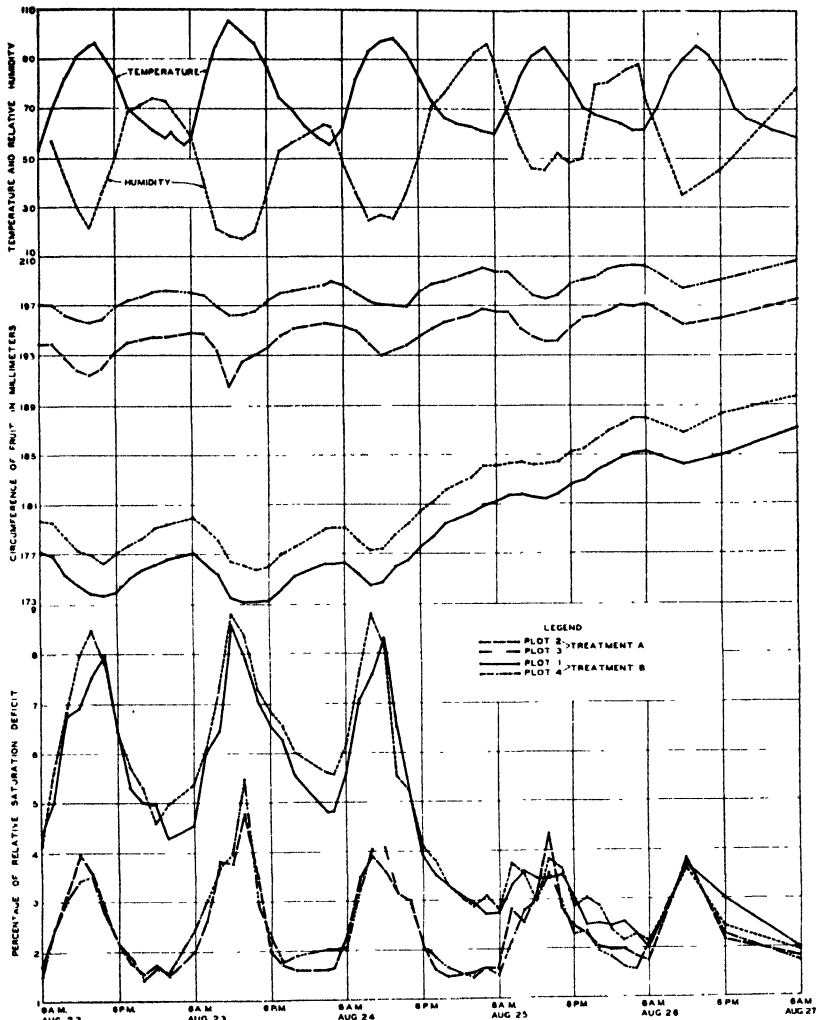


FIG. 3. Relative saturation deficit of Navel orange leaves and changes in size of fruit.

9:00 a.m., and ran for 24 hours, at the end of which time the water had penetrated 4 feet or more. Average penetration by noon was 12 to 18 inches; by 4:00 p.m., 18 to 24 inches.

The R.S.D. in treatment B varied from 4.3 per cent at 4:00 a.m. to 8.8 per cent at 12:00 noon before the irrigation, while that on treatment A ranged from 1.4 to 5.4 per cent with small variations from August 22 to 31 inclusive. The effect of the irrigation on treatment B was not noticeable until over 3 hours after irrigation started. Decrease in the R.S.D. was rapid thereafter until 6:00 a.m. of the next morning. The

R.S.D. was practically the same for both treatments by 2:00 p.m. on August 25, and for the rest of the sampling period.

The mid-day shrinkage of fruit on treatment A was greatest between 12:00 noon and 2:00 p.m. of each day, while for the 2 days prior to irrigation, August 22 and 23, the minimum size for treatment B occurred from 2 to 4 hours later. Maximum size occurred about 6:00 a.m. with both treatments. The response of the fruit to irrigation was apparently more rapid than for the leaves, for the daily minimum shrinkage on treatment B occurred only 1 hour after the water was turned on. Increase in size was rapid and continuous until 10:00 a.m. of the next morning. The mid-day shrinkage on treatment B for August 25 was small but thereafter was comparable to that on treatment A.

A third period of sampling was started on November 7 during a strong north wind. The wind started about 5:00 p.m., 3 hours before the first observations were started, and continued throughout the night except for occasional calms around 4:00 a.m.

The R.S.D. was greater during the windy period than on the following day with no wind but with lower humidity and a higher temperature at noon. Differences are slight, however. Fruit circumference variations were small, minimum values occurring at 8:00 p.m. on November 8 following a day of strong wind. Soil moisture samples taken November 9 showed that most of the soil in the irrigated area was above the P.W.P.

No clear diurnal trend occurred, as was found 2 months previously. These observations are presented in Fig. 4.

The data presented cover three factors that distinctly affect the water deficit in citrus, high air temperature, lack of available soil moisture, and strong wind. High temperatures produced no appreciable differences in the R.S.D. between plots in which the soil moisture was above the P.W.P. but which had been irrigated at periods of 5 and 36 days prior to the observations.

Low soil moisture in contrast to soil moisture well above the P.W.P. caused a marked difference in the R.S.D. When

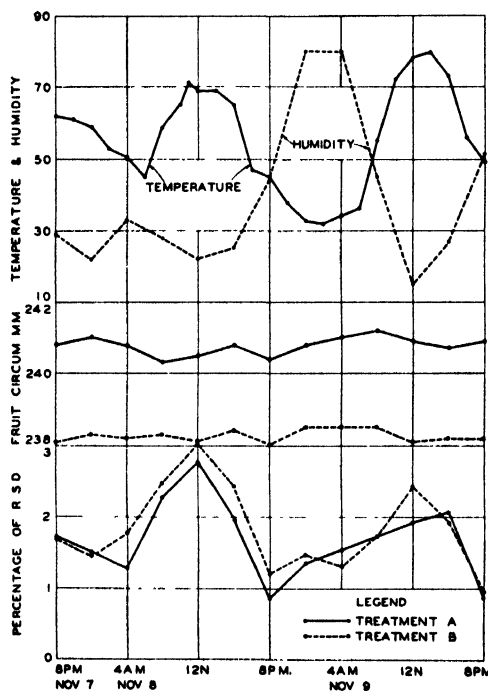


FIG. 4. Relative saturation deficit of Navel orange leaves and changes in size of fruit during a period of strong wind.

irrigation water was applied these differences were obliterated, but not until after a period of several hours had elapsed. Increase in circumference of fruit, on the other hand, followed within an hour or two after addition of water. The R.S.D. and the increase in size of fruit were practically the same in both treatments for an additional period of at least 6 days.

Strong wind and low humidity accompanied by adequate soil moisture produced a somewhat higher R.S.D. than on the following day without wind but there was no difference between treatments.

Under the conditions of high temperature and low humidity which prevail at Riverside during the summer lack of available soil moisture appears to be the most important factor in producing a high relative saturation deficit in leaves of the Washington Navel orange.

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Effect of Extent and Temperature of Roots on Transpiration of Rooted Lemon Cuttings

By J. BIALOGLOWSKI, *University of California, Los Angeles, Calif.*

A PREVIOUS study (1) on the water loss of rooted leafy lemon cuttings has shown that the effects of atmospheric vapor pressures on transpiration might be materially modified by conditions affecting absorption of water. The present report deals with the rate of transpiration in a constant environment as related to the temperature of the medium containing the roots and to the amount of root surface.

MATERIALS AND METHODS

Eureka lemon cuttings each possessing four mature leaves were taken from 1-year-old terminal growth and rooted in sand. The advantages in using this plant material and the methods of handling it have already been discussed (1). The plants were 3 to 3½ months old when transferred to nutrient solution. Sixteen plants constituted a set except where otherwise noted. Each plant was placed in a quart mason jar equipped with a special lid, which was screwed in at the neck of the jar and made to rest on the bath top. Thus, the jar with the roots in the nutrient solution was in direct contact with the water in the thermostatically controlled bath. The fluctuations in root temperature were less than 0.1 degree C.

This bath was placed in an air conditioned chamber of the controlled environment equipment of the Division of Subtropical Horticulture at the University of California, Los Angeles. In all tests reported here the aerial portions of all plants were subjected to approximately the same conditions, that is a temperature of 25 degrees C, a humidity of 60 to 65 per cent, light intensity of about 300 foot candles, and an average air velocity of 130 feet per minute. During the 12-hour period of darkness the atmospheric conditions were essentially the same as during the 12-hour period of illumination with some minor exceptions in series II when the humidity at night was higher.

Transpiration losses were determined on a balance equipped for rapid weighing. Since the jars were immersed in water, thorough wiping was necessary before weighing. It was ascertained that the error due to drying was .005 grams, while the water losses were recorded to the second decimal only. At lower temperatures condensation took place and tended to increase this error. However, even at those conditions it was possible to keep it at a low value due to a rapid and standardized method of weighing.

The procedure employed in measuring the root surface consisted of separating primary, secondary, and tertiary roots, and taking many diameter and root length measurements in each of these fractions. It was assumed that root surface = average diameter $\times \pi \times$ total length. The main error was involved in the determination of the diameter. For this purpose a precision dial caliper made it possible to take readings to 0.1 millimeters. However, due to pressure exerted by the contact points of this instrument the error actually was 0.2 millimeters. Considering

a typical case of a total root length of 100 centimeters and with a diameter of 1.0 mm the actual variation caused by this error was about 15 per cent. Of course, the dry weight of the roots could be estimated more accurately. It shall be pointed out later that with this type of plant a definite correlation between root surface and root dry weight can be established.

DISCUSSION OF RESULTS

Effect of Root Temperature on Transpiration:—In Fig. 1 the water loss at the various root temperatures was computed as per cent loss at 25 degrees C for the period of illumination. Each point represents the average of a series. Twelve hours were allowed for adjustment between treatments. Table I (series II) shows distinctly that each plant followed the same course when subjected to root temperature changes. Generalizing these results it may be said that the daily loss of water from leafy lemon cuttings under constant top conditions is unaffected by root temperature changes from 25 to 30 degrees C. The value at 35 degrees C is in the border zone of significant deviations from the loss at 25 degrees C. A very marked retardation of the transpiration rate takes place at root temperature below 25 degrees and above 35 degrees C. During the period of darkness there is no effect of root temperature at all. This can be accounted for by the fact that the water loss for the night period at 25 degrees C is less than that for the period of illumination at 0 degrees C. Haas (3), working with the same material, but planted in soils, maintains that there is an increase in water loss with an increase of soil temperature from 19 to 31 degrees C. He used different sets of plants for the various conditions and made comparisons on the unit leaf area basis. Presently it will be pointed out that under certain conditions this unit is not satisfactory. In this study all plants in a series were subjected to all treatments.

Considering Fig. 1, again, a discrepancy can be observed between series I and series II at lower root temperatures. This discrepancy may be explained by the fact that in series I the plants were exposed for 1 day only at each of the following root temperatures: 15 degrees, 10 degrees, 5 degrees, and 0 degree C. In series II the minimum exposure was 2 days. A reduction in transpiration losses from day to day took place at the low and at the excessively high root tempera-

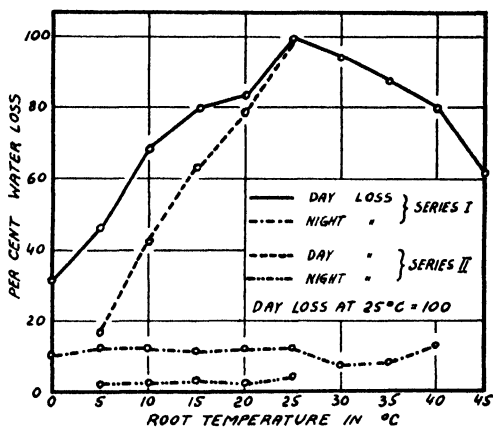


FIG. 1. Effect of root temperature on the rate of transpiration of rooted lemon cuttings.

tures. One might, also, emphasize that these two sets consisted of entirely different plants propagated at different times of the season. It will be noticed that appreciable water loss was obtained at a root temperature of 0 degree C. This is contrary to Clements' and Martin's (2) conclusion on the basis of extrapolation that the loss is close to 0 at a root temperature approaching 0 degree C. True, there was a pronounced decrease in turgor at this temperature, but the water loss frequently amounted to about 50 per cent of the water content of the leaves. If there is any root activity going on at 0 degree C, presumably the process of absorption would continue.

Effect of Extent of Root on Transpiration at Various Root Temperatures:—It has been repeatedly observed that the reduction of transpiration losses to the unit leaf area basis does not eliminate variabilities between plants. In Table I the cuttings are arranged in ascending order

TABLE I—TRANSPIRATION IN GRAMS PER PLANT DURING THE PERIOD OF ILLUMINATION IN RELATION TO ROOT TEMPERATURE (SERIES II)

Leaf Area (Sq. Cm.)	Root Temperature (Degrees C)				
	25	20	15	10	5
149	9.66	7.55	6.00	4.21	1.14
174	10.04	7.99	6.21	3.71	1.41
176	9.38	7.18	5.49	3.26	1.11
179	9.51	7.69	6.15	3.84	1.33
191	8.19	7.22	5.49	3.83	1.36
195	5.66	4.96	3.46	3.28	1.67
196	9.38	8.41	6.62	5.08	1.84
198	7.71	6.44	5.30	4.30	1.80
200	11.09	9.58	7.62	4.26	1.42
201	8.54	7.42	6.16	4.67	1.52
201	11.59	9.37	7.50	6.03	2.22
230	13.65	9.78	8.08	4.14	1.60
231	15.93	11.39	8.59	4.22	1.54
243	13.28	10.69	8.28	5.14	1.85
258	14.78	11.63	9.48	5.22	2.10
330	18.43	13.35	10.76	8.17	3.37
Average	11.06	8.79	6.96	4.59	1.68

based on total leaf area per plant. While some of the larger plants exhibit high water losses, this behavior is neither proportional nor consistent. It became necessary to search for a possible cause in variations of the absorbing surfaces. When transpiration per square decimeter of leaf area is plotted against the surface or dry weight of roots per unit area a curve resembling the saturation type is obtained. There is nearly a straight line relationship between water loss and extent of roots in the region below the limiting value for root surface or root weight. The curve in Fig. 2 is to be compared with that in Fig. 3 at 25 degrees C. In the former the position of the breaking point is not definite due to the large deviation of the points from the curve. It might be anywhere between .25 and .35 for the root surface-leaf area ratio. On the other hand in Fig. 3 there is a sharp break in the loss of

water per unit area at 130 milligrams of oven dry roots per square decimeter of leaf area. Consequently, above this value, where the amount of roots is not limiting the water loss, the leaf area is a more suitable unit for expressing the results than below this value.

In Fig. 3 the curves for root temperatures of 20 degrees and 10 degrees C were omitted since they merely exhibited intermediate gradations between 25 and 15 degrees, and 15 and 5 degrees C, respectively. Evidently, at lower temperatures the limiting factor for water loss is shifted from the amounts of roots available to the temperature of the medium surrounding them. The significant feature of these results is that the plants with a root system well above the limiting one suffer proportionally at least as much reduction in transpiration when transferred to lower root temperatures as do those with a root surface less than sufficient to start with. Had the effects of root temperature been of a physical nature a different behavior would be expected. The physiological character of those effects is borne out, also, by the fact that the temperature coefficient $Q_{10} = 1.6, 1.9,$ and 4.1 for the temperature drop from 25 to 15 degrees, 20 to 10 degrees, and 15 to 5 degrees C, respectively. This coefficient for viscosity of water and for osmometer is much lower. Apparently the activity of the entire root system is affected.

Effect of Root Removal on Transpiration at a Constant Root Temperature of 25 Degrees C:—In order to test this root activity more closely a third set of plants was subjected to progressive root removal. The method of cutting consisted in either removing completely one or more primaries or cutting them back to one-half or two-thirds of their length. The latter procedure was used for plant No. 6 on June 1, for Nos. 1, 2, and 6 on June 4, and for plant No. 1 on June 8. In the

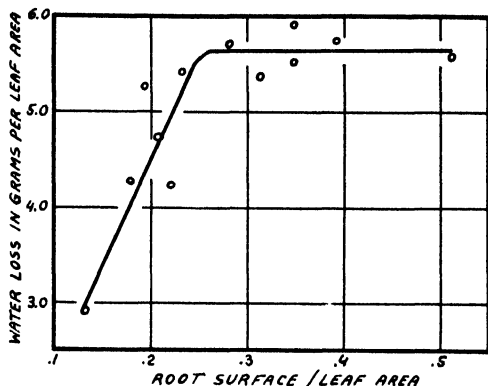


FIG. 2. Transpiration in relation to root surface at a root temperature of 25 degrees C.

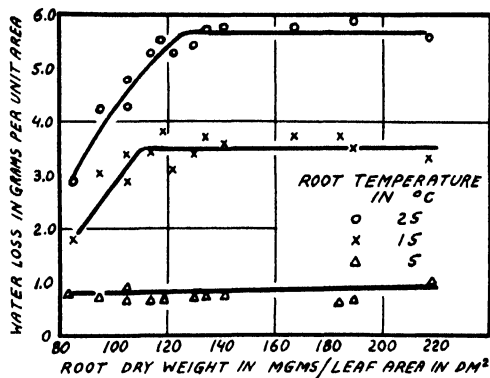


FIG. 3. Transpiration at various root temperatures as affected by weight of roots.

remainder entire primaries were removed. The cutting was done on evenings after transpiration for the illumination period was recorded. All cut surfaces were covered with low melting point paraffin. The severity of cutting and the subsequent water losses are indicated in Table II. In all cases root removal resulted in a decreased water loss

TABLE II.—DAILY WATER LOSS PER PLANT IN RELATION TO ROOT REMOVAL AT CONSTANT ROOT TEMPERATURE (SERIES III)

Plant Number	1	2	3	4	5	6	7	8	9
May 25, 1936	10.14	7.16	15 04	11 18	10.15	9 04	12.40	9.86	9.49
May 28	12.63	7 01	16.09	12.78	11.41	9.14	12.25	10.97	10.90
May 29 . . .	13.29	6.52	16.84	13.39	12.65	8.57	10.57	10.67	10.67
Per cent roots cut	68	20	— —	— —	— —	61	28	63	23
May 30 . . .	5.54	4 95	14 98	11.96	10.70	4.49	5.20	5.40	7.41
May 31 . . .	5.51	4.87	15.77	12.89	11.43	4.03	4.59	4.46	7.16
June 1 . . .	5.17	4.71	14.47	12.23	10.89	3 60	3.97	3.95	6.69
Per cent roots cut	10	29	— —	— —	— —	18	49	— —	— —
June 2 . . .	2.95	3.94	15.28	12.33	11.31	3.67	3.28	4.26	7.17
June 3 . . .	2.79	4.06	15.75	13.28	11.84	3.61	3.26	4.39	7.39
June 4 . . .	2.69	4.09	16 41	12.65	11.25	3.34	3.17	4.22	7.17
Per cent roots cut	8	20	— —	54	—	12	13	14	39
June 6 . . .	2.81	2 72	14.57	7.83	10 65	2.42	1.96	2 77	3.30
June 7 . . .	2.78	2.57	15.38	7.79	11.01	2.39	2.05	2.79	3.46
June 8 . . .	2.90	2.16	12 49	6.41	10.22	2.20	1.96	2 68	3.35
Per cent roots cut	7	20	— —	39	—	8	—	13	21
June 9 . . .	1.92	1.35	12 54	2.40	10 39	1.23	1.87	2.38	1.72
June 10 . . .	1.58	1.25	11.99	1.14	10 70	.73	1.80	2 40	1.30
June 11 . . .	1.89	1.39	11.80	1.06	9.87	.61	1.83	2.73	1 15
June 12 . . .	1.86	1.29	12.44	1.11	10.23	.68	1.76	2.94	1.31

the following day. No shock effect was observed, though there might have been one immediately following cutting. This table, also, illustrates the degree of variability of transpiration results under constant conditions. Considering the deviations from the average for the 136 readings it was found that 96 were below 5 per cent, 22 between 5 and 10 per cent, 14 between 10 and 15 per cent, and four readings above 15 per cent. The water losses for plants 2 and 4 for the period of June 9 to June 12 were excluded for these calculations, because at that time these plants were in a wilted condition. Since 87 per cent of the deviations were below 10 per cent, one might consider increases or decreases in transpiration above this value as reasonably significant. Certainly, differences larger than 15 per cent are due to treatment.

In Figs. 4 and 5 all the transpiration values, including those for the check plants, are plotted against the root surface/leaf area, and root dry weight/leaf area ratio. A striking similarity between these curves and the corresponding ones in Figs. 2 and 3 can be observed. This is of particular significance in view of the fact that series II included a different set of plants which was not subjected to any root removal. Here, as well as above, root dry weight gives better results

than root surface. The breaking point in Fig. 4 is at a value of .35 for root surface/leaf area which is close to that in Fig. 2. The limiting amount of roots expressed in milligrams of dry weight of roots per square decimeter of leaf area is 125 in series III, while in series II it is 130. We are inclined to explain the closer agreement with the dry weight ratio by the greater reliability of determining root weight. A more precise method in estimating root surface would presumably indicate a closer correlation with the latter than with root weight. Fortunately, with this type of material, in which there is little variation in the diameter of the roots, a direct relation of surface to weight can be established. This fact is clearly shown in Fig. 6.

If the line in Fig. 5 should be extrapolated to 0 root weight the loss per unit area will amount to .25 grams per square decimeter. Actually plant No. 6 was deprived of all its roots and was transpiring .41 grams for 4 consecutive days. This value doubtlessly included part or all of the water content of the leaves. On the fourth day it was permanently wilted. This leads us to the all important question: how much water must the plant transpire for normal activity? Plants 2 and 4, when their water loss was reduced to 19 and 12 per cent, respectively, of

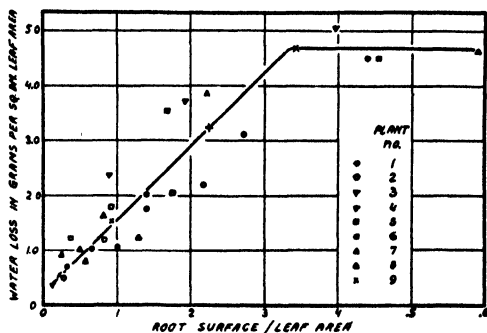


FIG. 4. Transpiration in relation to root surface as affected by root removal.

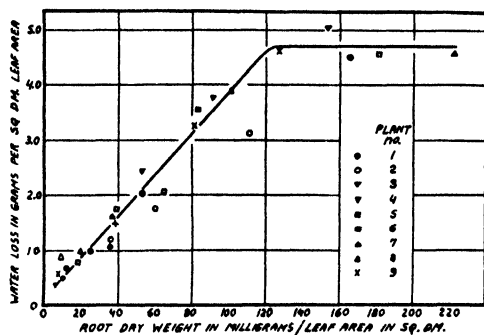


FIG. 5. Transpiration in relation to root weight as affected by root removal.

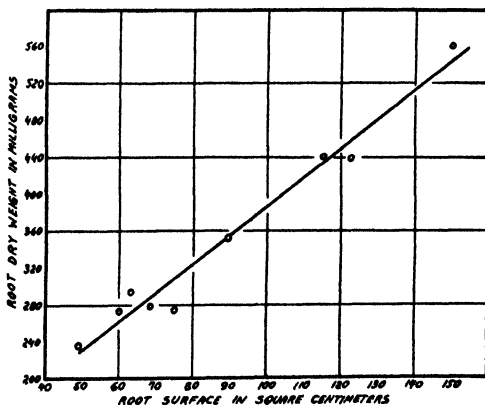


FIG. 6. The relation of root dry weight to root surface in lemon cuttings.

their original loss, were curled; plant No. 1 exhibited decreased turgor at 15 per cent, while No. 8 at 25 per cent appeared normal. None showed signs of distress when the loss was $\frac{1}{4}$ to $\frac{1}{5}$ of the loss before root removal. However, these considerations are not sufficient in concluding as to the water requirements of lemon cuttings under these conditions. The fact that plants can withstand a certain reduction in transpiration without being visibly affected does not mean necessarily that their metabolism is normal. This point might be elucidated by relating transpiration to other physiological processes like respiration or mineral absorption. These results suggest that a study of water requirements in plants must not only include climatic differences but also conditions affecting absorption.

CONCLUSIONS

1. Rooted leafy lemon cuttings subjected to changes of root temperature at constant top conditions transpire during the period of illumination most actively at 25 and 30 degrees C. The rate of water loss is slightly retarded at 35 degrees, and very markedly at root temperatures above 35 degrees and below 25 degrees C.

2. Transpiration during the period of darkness is unaffected by root temperature changes within the range of 0 to 40 degrees C.

3. At a root temperature of 25 degrees C the amount of roots required for transpiration under these experimental conditions is at least 130 milligrams of root dry weight per square decimeter of leaf area. At lower root temperatures there is a shift of the limiting factor from extent of roots to root temperature.

4. This limiting value of 130 milligrams has, also, been found in the case of progressive root removal. Transpiration could be reduced $\frac{1}{4}$ to $\frac{1}{5}$ of its original value without visibly affecting the plants.

5. A direct relationship between root dry weight and root surface has been established for this plant material.

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Observations on the Effects of Gas Storage Upon Valencia Oranges¹

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WITH the prolongation of the marketing season of citrus becoming more and more important for a number of countries, the question of gas storage, which has shown promise with other fruits, is of considerable interest. The material discussed below is the result of a preliminary trial in this direction.

Freshly picked Valencia oranges were numbered and weighed; all fruits below 120 grams and above 150 grams were discarded. One hundred eighty fruits were placed into each of 12 tanks of 18 liters capacity. Three tanks were placed into each of four constant temperature rooms at 32, 36, 45 and 70 degrees F. Through one of them a current of air was passed and through the second nitrogen which contained 1 per cent oxygen. In both tanks the CO₂ concentration was kept below 1 per cent. Through the third tank a mixture of air and CO₂ containing between 18 and 22 per cent CO₂ was passed.

The tanks were opened after 3 months. About half the fruits which had been stored at 70 degrees F had rotted from *Colletotrichum* infection and a few in each tank from *Penicillium*. There seemed to be no significant difference between infections under different gas treatments. At 45 degrees F there were on the average in each tank five fruits affected by *Colletotrichum* and two with *Penicillium*. No infections occurred at 36 and 32 degrees F.

The CO₂ treatment produced a specific injury of the rind. There developed at the distal end of the fruit sunken spots which in an advanced stage of injury tended to flow together and finally formed a discoloration and browning of the sunken areas. These were confined to the flavedo and did not seem to affect the albedo. The development of the injury seemed to be promoted by higher temperature. While at 32 degrees only slightly sunken spots were visible, the symptoms progressed with higher temperatures up to 45 degrees as described above. A definite statement concerning the parcel kept at 70 degrees is difficult because of the considerable amount of decay found in the fruit. The taste did not seem to be materially affected by the CO₂ treatment, while the fruit stored under nitrogen possessed a pronounced off taste, with quite a disagreeable and somewhat bitter after taste. There was no visible injury in this fruit.

Samples of 25 fruits each were taken for chemical analysis. Peel and pulp were separated, the vascular core added to the peel and frozen in a CaCl₂ freezing mixture and stored at -12 degrees C. Before use the material was ground in a cold storage room and mixed while still frozen. Aliquots of 25 grams were used for sugar determinations. The alcoholic extracts were dried in vacuo, cleared with basic lead acetate and delead with Na₂HPO₄. Inversion was made by means of invertase. Reducing power was determined according to the method of Lane

¹Work done in Division of Plant Nutrition, University of California, Berkeley.

TABLE I.—THE EFFECT OF THREE MONTH'S GAS STORAGE UPON THE COMPOSITION OF VALENCIA ORANGES. (AS PER CENT OF FRESH WEIGHT)

Part of fruit	Pulp						Peel					
	Before Storage			After Storage			Before Storage			After Storage		
		Air	45	Nitrogen	36	45		Air	45	Nitrogen	36	CO ₂ and Air
Time of sampling												
Storage atmosphere												
Storage temperature (degrees F)												
Total sugars	9.8	7.9	7.9	8.6	8.1	8.3	8.4	3.9	5.8	6.2	6.4	5.9
Reducing sugars	5.7	4.4	4.4	4.7	4.5	4.8	4.7	2.8	4.7	5.3	4.7	4.7
Sucrose by difference	4.1	3.5	3.5	3.9	3.1	3.5	3.7	1.1	1.1	0.9	1.7	1.2
Glucose	3.0	2.8	2.8	3.1	2.9	2.8	2.6	2.4	3.9	4.1	3.3	3.0
Fructose by difference	2.7	1.6	1.6	1.6	1.6	2.0	2.1	0.4	0.8	1.2	1.4	1.7
Glucose/fructose	1.1	1.8	1.9	1.8	1.4	1.4	1.2	6.0	4.9	3.4	2.4	1.8
Glucoside	0.37	0.37	0.0	0.0	0.0	0.0	0.0	0.94	0.81	0.81	0.94	0.94
Titrate acid	0.63	0.57	0.57	0.57	0.56	0.60	0.52	0.24	0.22	0.24	0.23	0.22

and Eynon (2). Glucose was determined by iodide reduction (1) at 36 degrees F. A relative value for glucoside was obtained by subtracting the reducing values which had been obtained for the diluted material when treated with invertase alone, from those which had been obtained after treatment with invertase plus emulsin. Citric acid was determined by titration. The results are reported as per cent of fresh weight, since the weight of the oranges and the relative proportion of pulp and peel had not changed appreciably during storage owing to the large free water surface that was kept in the storage tanks and the passing of the gases through water before entering the tanks. Because of unavoidable circumstances only part of the samples could be analysed. These are reported in Table I.

Decline in total sugars would be expected to reflect relative rates of the major part of respiratory processes. The data show clearly that the heavier losses were sustained in air. However, while the pulp lost in air about 19 per cent of its original sugar content, the peel respired as much as 54 per cent. Furthermore, there is relatively little difference between different treatments as to the amount of sugar respired in the pulp. At 45 degrees F the pulp in nitrogen lost 17 per cent, at high CO_2 concentration 14 per cent and in air 19 per cent of their sugars. On the other hand, there are more pronounced differences in the peel which lost in nitrogen 27 per cent and in the CO_2 -air mixture 31 per cent of the sugars as compared with 54 per cent in pure air. Correspondingly the individual sugars show a greater variability in the peel than in the pulp. Both show a certain amount of sucrose inversion during storage. There do not seem to appear consistent differences in inversion under different treatments. There are definite indications that CO_2 affects the glucose/fructose ratio. While this ratio is 1 in the pulp before storage it rises during storage in air and under nitrogen to close to 2. Under CO_2 , however, it rises only to 1.4 and 1.2 respectively. A similar relative behavior is observed in the peel where the ratio changed little in the CO_2 mixture while it increased considerably under nitrogen and in air. This difference in glucose/fructose ratio between fruit stored in nitrogen and that stored under CO_2 is so much more interesting in view of the fact that the respective concentrations of reducing sugars do not show any consistent differences. Data obtained for glucoside concentrations suggest that they take part in respiration. Yet it is questionable whether differences obtained in peel under CO_2 and nitrogen treatments are significant in view of the crudeness of the method used. Any such differences might be of interest in connection with the bitter taste observed in fruit kept under nitrogen. The smallness of the amount of respiration of the acid is remarkable. Yet it should be borne in mind that the citrate present as salt was not determined in this analysis.

While the reported results give rise to a number of questions concerning the metabolism of the fruit, further work is required for detailed physiological interpretation. Thus there would seem to appear a very definite indication that diffusion of gases to and from the interior is greatly impeded and that there is a highly anaerobic state within the fruit even with an ample supply of oxygen in the external atmos-

phere surrounding it. This would afford an explanation for the fact that the rate of respiration as indicated by the loss of sugar was almost three times as high in the peel as in the pulp. Furthermore, it would account for the effect of different gaseous environments upon sugar consumption and glucose/fructose ratio being so much more pronounced in the peel than in the pulp. These facts could, however, also have been brought about if the actively respiring substance were more concentrated in the peel than in the pulp. If we assume organic nitrogen to be correlated with respiring substance, then it is of interest to know that the Shamouti orange was found to contain 2 to 3 times as much nitrogen in fresh peel as in pulp.² This would correspond well with the relative figures for sugar consumption reported above.

In view of the small differences in change of composition of the edible portion of Valencia oranges between different extremes of gaseous environment it would seem that gas storage of oranges would be of minor practical importance. On the other hand, storage of oranges at low temperatures did not cause any harmful effects and was shown here again to be very effective in the control of decay.

The author wishes to express his indebtedness to Dr. J. P. Bennett for his assistance and valuable suggestions given throughout the experiment.

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²Unpublished data of Div of Chemistry, Agricultural Research Station, Rehovot, Palestine.

Fruit Thinning Experiments With Deglet Noor Dates

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FRUIT thinning is a regular commercial practice in the date gardens of the Southwest, particularly in the Coachella Valley of California with Deglet Noor, the variety that composes more than 80 per cent of the present acreage of imported varieties. As large blocks of palms began to come into bearing more than a decade ago it was soon found that when the number of dates per bunch was not reduced the fruit was undersized and much of it shrivelled prematurely, especially near the tips of the strands. This led to the present method of thinning. When pollinating the operator cuts back the tips of the strands for a certain proportion of the flowering area. At that time the operation is easily done with a single cut since within the freshly opened spathe the branches of the flower cluster are compact and relatively tender. At the same time some growers also cut out entirely a certain proportion of the strands from the center, although most of them postpone this part of the thinning for several weeks after the close of the pollination season until the bunches have begun to work their way down through the leaves and it is easier to see just how much more it is desirable to remove. At this later period some of the bunches are cut out if the number is in excess of what seems desirable for the size and vigor of the palm.

It was reported from the Arizona Agricultural Experiment Station as early as 1915 (2) that thinning had increased the size of dates and in some instances accelerated the time of ripening. More recently at the same station Albert and Hilgeman (1) reported increased size of fruit and more uniform ripening as a result of thinning. However, as original data were not published in either case it has not been possible to evaluate the several conclusions contained in these reports. The evolution of thinning in Coachella Valley has been based on the experience of growers, but while the present thinning procedure has been generally adopted as to method there has not been unanimity of opinion as to amount. It was obvious that thinning increased the size of fruit, but as to other effects incident to varying percentage reductions of fruit opinions have been diverse and observational evidence inconclusive.

Investigations of metaxenia in dates by the senior writer (3, 4, 6, 7) having shown that pollen may affect directly the size of fruit and time of ripening, attention was naturally directed to other factors such as thinning that might influence the same attributes. In cooperation with commercial growers in Coachella Valley fruit thinning experiments were conducted in 1934 and 1935. Reports of this work have already been presented to the date growers by the senior writer (8, 9).

EXPERIMENTAL PROCEDURE

The first year four rows of 11 palms each, planted in 1927 and about as uniform as can be found in a commercial planting, were used for the tests. Each row was given a different thinning treatment as follows: (a) no thinning; (b) commercial thinning as practiced in this

date garden—cutting back the tips of the strands enough to remove about one-third of the dates (or flowers at this stage in their development) and in addition cutting out entirely a few of the strands in the center of the bunch, making a total reduction of about one-half, all done at time of pollination; (c) same as (b) except that the number of dates on the strands was reduced about two-thirds, making the total reduction about three-fourths; (d) same as (c) except that the thinning was done on June 1st, the approximate time when most of the secondary thinning is completed.

The second year in another garden further tests were made with three rows of 10 palms each, planted in 1928. Instead of the extremes of no thinning and very severe thinning, gradations of thinning set for the experiment were as follows: (a) light thinning—cutting back the tips of the strands enough to remove 10 per cent of the flowers and cutting out 15 per cent of the strands from the center; (b) moderate thinning—cutting back the tips enough to remove 30 per cent of the flowers and cutting out 30 per cent of the strands from the center; and (c) moderately severe thinning (referred to subsequently as “heavy” thinning)—cutting back the tips enough to remove 50 per cent of the flowers and cutting out 30 per cent of the strands from the center. If all the strands carried the same number of flowers this would give a theoretical reduction of 23.5 per cent, 51 per cent and 65 per cent respectively. However, there is considerable variation in length of strands and number of flowers thereon. Furthermore in thinning dates it is only possible to approximate any definite percentage reduction because most of the thinning must be done before the set and subsequent shedding are determined. The second year's thinning was delayed for a few days after the pollination of individual clusters to facilitate a more accurate percentage reduction based on estimates from flower counts of a few typical strands, but for all practical purposes it may be considered as thinning at time of pollination.

RESULTS

The experimental data from these tests are summarized in Tables I and II and Figs. 1 and 2. In Table II the theoretical reduction in dates per bunch is assumed for the percentage reduction in the light thinning treatment and the comparative reduction percentages for the other two treatments are based on this in relation to the calculated number of dates per bunch. The data for set, shedding, shrivelling, checking and blacknose were obtained from the examination of individual dates on three typical strands of every bunch, the last three observations being made just prior to the first picking in September. The size data are based on random samples of 10 dates from each palm taken just prior to the first picking in 1934 and between the second and third pickings in 1935. The fruit was harvested by commercial pickers in both gardens. Yields were recorded by treatments and from the season's totals the yields per bunch were calculated. Figures 1 and 2 are based on the picking records.

TABLE I—FRUIT THINNING DATA FROM KRUTZ GARDEN, 1934

	No Thinning	Light Thinning at 1st Time of Pollina- tion	Heavy Thinning at Time of Pollination	Heavy Thinning June 1
Average number of dates per strand	41.9±0.45	27.0±0.50	15.5±0.34	13.9±0.24
Reduction of dates per strand (per cent)	0	35.6	63.0	66.8
Average number of strands per bunch	57.7±0.76	39.5±0.43	35.8±0.35	41.9±0.71
Reduction of strands per bunch (per cent)	0	31.5	38.0	27.4
Number of dates per bunch—calculated	2417.6	1066.5	554.9	582.4
Reduction of dates per bunch (per cent)	0	55.7	77.0	75.9
Average ratio of abscission scars to number of dates per bunch (per cent)				
Average percentage of dates prematurely shrivelled per bunch	22.0±0.59	47.4±1.76	46.9±1.68	63.0±2.57
Average percentage of dates checked per bunch	14.8±0.86	1.3±0.17	1.1±0.18	0.8±0.11
Average percentage of dates with blacknose per bunch	2.6±0.65	33.7±1.16	38.9±0.98	32.9±0.93
Average length of dates (mm)	0	5.1±0.48	18.1±0.87	17.5±0.98
Average breadth of dates (mm)	37.2±0.15	41.0±0.12	43.8±0.14	42.3±0.13
Average length of seeds (mm)	17.2±0.08	19.9±0.08	22.0±0.08	20.3±0.07
Average breadth of seeds (mm)	23.2±0.08	24.2±0.08	25.0±0.10	24.1±0.10
Yield per bunch—calculated (pounds)	6.9±0.03	7.2±0.03	7.2±0.03	7.2±0.03
Reduction of yield per bunch (per cent)	25.38	19.08	14.67	10.92
Increase in weight per date (per cent)	0	24.8	42.2	57.0
Grade yields—calculated	0	26.2	59.4	30.2
A: Per cent				
Number of pounds per bunch	5.2	4.5	5.5	2.0
Number of dates per pound	1.32	0.86	0.74	0.22
B: Per cent				
Number of pounds per bunch	50.7	42.2	35.8	42.4
Number of dates per pound	42.3	54.1	53.4	39.4
C: Per cent				
Number of pounds per bunch	10.74	10.32	7.24	4.30
Number of dates per pound	56.1	44.9	36.6	42.9
Number of pounds per bunch	45.8	38.9	39.3	55.3
Number of dates per pound	11.62	7.42	5.31	6.04
Culls: Per cent	62.8	47.9	37.1	47.0
Number of pounds per bunch	6.7	2.5	1.9	3.3
	1.70	0.48	0.26	0.36

TABLE II—FRUIT THINNING DATA FROM BOYER GARDEN, 1935

	Light Thinning	Moderate Thinning	Heavy Thinning
Average number of dates per strand . .	29.6±0.64	22.1±0.42	12.2±0.26
Reduction of dates per strand (per cent)	10.0	37.4	62.8
Average number of strands per bunch	41.9±0.76	37.2±0.55	37.2±0.52
Reduction of strands per bunch (per cent)	15.0	24.7	24.5
Number of dates per bunch—calculated	1240.2	822.1	453.8
Reduction of dates per bunch (per cent)	23.5	49.4	72.0
Average percentage of dates set per bunch	60.2±0.89	55.1±0.87	50.8±0.71
Average percentage of dates shed per bunch—			
June 8 to July 16	12.8±0.64	11.2±0.57	14.2±0.72
July 16 to September 18	5.1±0.31	7.9±0.40	17.0±0.57
Average percentage of dates prematurely shrivelled per bunch	6.8±0.74	2.7±0.25	1.0±0.14
Average percentage of dates checked per bunch	11.6±1.22	20.4±1.30	38.5±1.40
Average percentage of dates with blacknose per bunch	0.8±0.22	2.6±0.26	12.1±0.68
Average length of dates (mm)	40.2±0.41	42.5±0.15	45.1±0.14
Average breadth of dates (mm)	19.2±0.09	19.8±0.08	22.3±0.07
Average length of seeds (mm)	23.9±0.08	24.9±0.10	26.2±0.10
Average breadth of seeds (mm)	7.3±0.03	7.5±0.03	7.5±0.02
Yield per bunch—calculated (pounds)	15.76	14.75	9.96
Reduction of yield per bunch compared to light thinning (per cent)	0	6.4	36.8
Increase in weight per date compared to light thinning (per cent)	0	14.9	37.2
Grade yields—calculated			
A: Per cent	5.3	8.0	7.7
Number of pounds per bunch . .	0.84	1.18	0.77
Number of dates per pound . . .	42.4	37.8	32.6
B: Per cent	32.8	36.9	40.1
Number of pounds per bunch . .	5.17	5.44	3.99
Number of dates per pound . . .	45.4	40.5	34.4
C: Per cent	45.2	42.9	43.2
Number of pounds per bunch . .	7.12	6.33	4.30
Number of dates per pound . . .	52.7	43.2	36.3
Culls: Per cent	16.7	12.2	9.0
Number of pounds per bunch	2.63	1.80	0.90

Random samples of 100 dates per palm were taken from each picking and graded into A, B, C grades and culls. In establishing grades observations were first made on grading as practiced in local packing houses so that the standards set would conform fairly well to local usage. Grade A corresponds to "Fancy" and includes only fruit of good appearance and texture with no hard or dry portions. Grade C includes all the drier fruit which in commercial practice has more recently been generally subdivided into No. 1 and No. 2 "dry." Dates with pronounced blacknose were put in this grade. Grade B covers all fruit between A and C except culls and corresponds to "Choice." The samples from each palm were graded separately and the results

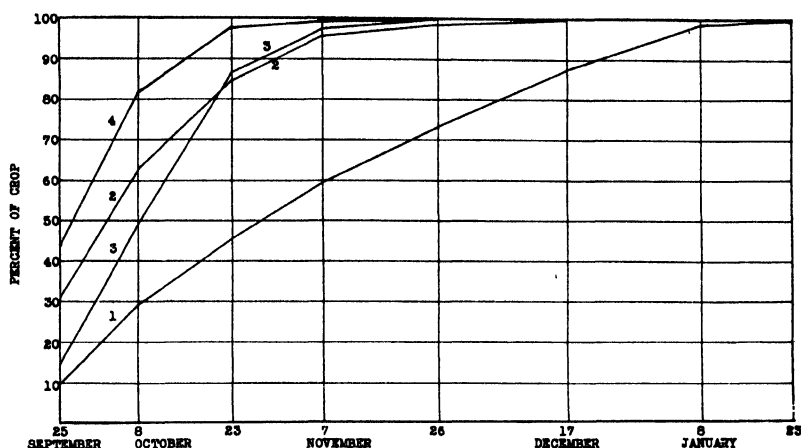


FIG. 1. Differences in time of ripening of Deglet Noor dates due to thinning, 1934. 1—No thinning; 2—Moderate thinning at time of pollination; 3—Heavy thinning at time of pollination; 4—Heavy thinning June 1.

averaged for each row. From these data the number of pounds of fruit of the different grades in each picking was calculated. In order to determine the effect of thinning on quality, size was not considered in grading, although arbitrary size standards are in commercial use for the Deglet Noor variety. The dates were weighed after grading and from these data the number of dates per pound for each grade was calculated.

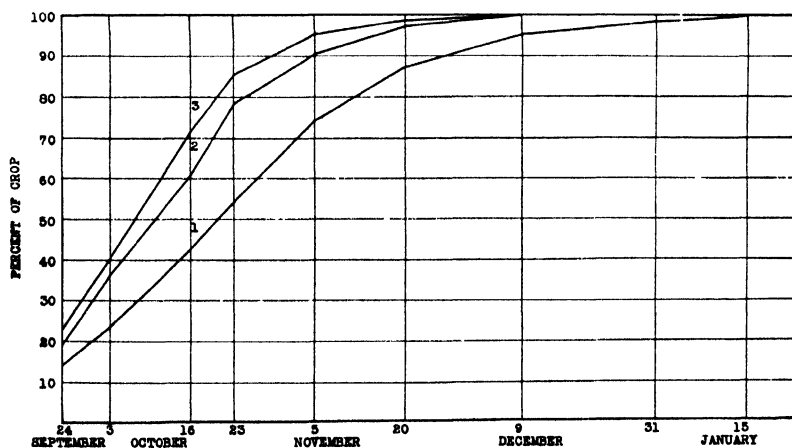


FIG. 2. Differences in time of ripening of Deglet Noor dates due to thinning, 1935. 1—Light thinning; 2—Moderate thinning; 3—Heavy thinning.

DISCUSSION

The set of fruit was not recorded in 1934, but an index to the total shedding of flowers and fruit is afforded by the ratio of abscission scars to number of dates. By abscission scars is meant the vacant places on the strands where flowers or dates had dropped off. The dates that dropped might have been pollinated or unpollinated and the shedding might have occurred any time prior to the check made just before the first picking in September. This ratio was increased by thinning. Although there is practically no difference in the two thinning treatments at time of pollination the ratio is higher in the case of heavy thinning June 1st. Part of this increase in shedding in the late thinning treatment is probably due to unavoidable bruising. It is almost impossible to handle a bunch of dates, quite heavy at this later period in their development, without a slight breakage in many of the fibers connecting the date to the strand. This difficulty in handling makes it commercially impracticable to delay the entire thinning operation beyond pollination and it was not attempted the following year.

In 1935 the percentage of fruit set, as checked on June 8, was found to have been decreased in proportion to the degree of thinning. The slight differences are probably explained by a previously observed tendency for a better set to occur near the tips of the strands than near the base, possibly due to more exposure to pollen. Incidentally, the set this season was below normal on these palms, as was the case very generally in date gardens throughout the Southwest. This accounts in part for the smaller number of dates per bunch in the nearly comparable treatments. Shedding was about the same in all treatments between June 8 and July 16, but between July 16 and September 18 there were significant differences in the amount of shedding which was increased by thinning, especially in the heavy thinning treatment. In this experiment the number of dates set was the basis for estimating shedding, so, confirming the increase in abscission scars already noted for the previous year, this may be taken as more definite evidence that thinning increases the amount of shedding.

In 1934 a large proportion of the unthinned fruit shrivelled in varying stages of immaturity; 15.6 per cent, as recorded prior to the first picking, would represent a serious loss to the grower if it involved his entire crop. In 1935 light thinning reduced shrivelling to about half that of the unthinned treatment of the previous year. Further increases in thinning reduced the shrivelling to what is probably very nearly a minimum, as a little of it almost always occurs in relatively dry seasons such as were both 1934 and 1935.

Every year on some Deglet Noor dates there occur in varying degrees small checks or breaks in the skin concentrated mostly in the apical half of the fruit. The proportion of fruit affected varies with season and garden. When the checks are numerous and severe they are usually accompanied by a shrivelling and darkening of the skin known commonly as "blacknose". One of the most striking results of the experiments was the increase in checking and blacknose accompanying thinning. Except in the case of heavy thinning June 1 in the 1934 tests, the increase in blacknose was also in proportion to size, but the

size of the dates heavily thinned June 1 was comparable to the size of the dates moderately thinned at time of pollination, while the percentage of blacknose was comparable to that of the dates heavily thinned at time of pollination. It has been shown by the senior writer (5) that one of the causal factors involved in the production of blacknose is humidity occurring at a certain stage in the development of the fruit. It now appears from these data that another causal factor involved in the occurrence of blacknose is the physiological condition of the fruit at the time when atmospheric humidity is conducive to checking.

The size of fruit was increased in direct proportion to the amount of thinning as is shown by both measurements and average number of dates per pound. And, as noted above, delayed thinning was less effective in increasing size. Although on the basis of total weight the unthinned fruit in Table I graded as A exceeded that in any of the other treatments in 1934, most of it would have been disqualified because the average size was below the commercial size standard of 1.5 inches in length and 45 dates to the pound. Most of the unthinned dates graded as A would have fallen into B grade commercially, while most of those graded as B, falling below the weight standard of 55 dates per pound for this grade, would have been classed as "Off-Grade" fruit. In 1935 the fruit in the light thinning treatment met the commercial requirements as to size, but both the percentage and the number of pounds per bunch of A grade were less than in the moderate thinning treatment. Observations on the results of grading indicate that in both years the percentage of A grade fruit in the heavy thinning treatments might have been higher but for the large percentage of blacknose. Due to the decreased yield it would have taken a considerable increase in percentage of A grade fruit to bring up the number of pounds per bunch to that of the moderate thinning treatment. Furthermore, during the past few years there has not been enough difference in the price returned to growers for A and B grades to warrant much sacrifice of B grade for the somewhat smaller proportionate increase in A grade possible to secure through thinning.

The unthinned dates, Fig. 1, ripened approximately 1 to 7 weeks later than any of the other treatments. With the unthinned dates it was noted further that often fruit with all appearances of being ripe contained more immature tissue around the seed than fruit of similar appearance from the thinning treatments. The earliest ripening in 1934 was from heavy thinning June 1. Between these limits were the two rows thinned at pollination, the moderate thinning being a little ahead in the early pickings but holding some of its fruit later than the heavy thinning. In 1935 moderate thinning resulted in an acceleration in ripening of approximately 2 weeks as compared with light thinning. Heavy thinning resulted in only a very slight acceleration of ripening as compared with moderate thinning—less than a week.

CARRY-OVER EFFECTS

In 1934 the palms in the unthinned row each produced from 8 to 18 spathes and were allowed to carry from 8 to 12 bunches, the other treatments being quite comparable in this respect. In the spring of 1935

only three of the 11 palms flowered at all and these three produced a total of only 20 spathes. Two of the eight palms that failed to flower in the spring produced off-season blooms in the summer, one having three and the other four spathes. In the moderately thinned row the total number of flower clusters in 1935 was slightly less than in the preceding spring but enough to produce a normal crop with one exception—this palm had only two spathes in the spring of 1935, followed by two off-season blooms the following summer. Also one palm that produced only nine spathes in the spring had one off-season bloom the following summer. Out of the 44 Deglet Noor palms in this experiment none that had 10 or more spathes in the spring of 1935 produced off-season blooms the following summer. From this evidence, even though rather meager, it seems probable that much of the summer flowering that occasionally gives concern to date growers may be traceable to a light crop of flowers the previous spring which in turn may be due to a very heavy crop the year before.

For the second thinning experiment the following data were recorded: in 1935 the palms used for light thinning produced 170 spathes and matured 99 bunches of fruit; moderate thinning, 147 spathes and 104 bunches; heavy thinning, 166 spathes and 122 bunches. In the spring of 1936 the same rows of palms produced spathes as follows: light thinning, 94; moderate thinning, 110; heavy thinning, 139. These data show clearly that a heavy crop one year, not the number of spathes produced, tends to reduce the number of spathes that appear the next spring.

SUMMARY

Fruit thinning experiments with Deglet Noor dates conducted in cooperation with commercial growers in Coachella Valley, Calif., in 1934 and 1935 resulted in an increase in size of dates proportionate to the severity of thinning. Delay in thinning decreased the effect on size. Without thinning a large percentage of the fruit shrivelled prematurely and the crop was very slow to ripen, many of the dates showing a tendency to mature imperfectly. Thinning accelerated ripening, although after the number of dates was reduced to the capacity of the bunch the effects of further thinning on time of ripening were slight. Checking and blacknose were increased in proportion to the amount of thinning regardless of the time of thinning. The only contributing cause of this physiological trouble previously known was the occurrence of humidity at a certain stage prior to ripening. The results of these experiments indicate that the physiological condition of the date at the time the humidity occurs is also a factor involved. The increased percentage of blacknose resulting from severe thinning proved a distinct detriment tending to offset any advantage from extra large dates or what might otherwise have been an increased percentage of higher grade fruit. Best results were secured from a total reduction at time of pollination of approximately 50 to 60 per cent in the number of dates per bunch. Thinning up to this point was largely offset by increased size of fruit with a larger proportion of higher grades and a decreased percentage of culls. Thinning beyond this point curtailed yields without having compensating advantages.

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The Effect of Time of Thinning on Apple Size¹

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IT has been shown (1) that with peaches late thinning (3 to 4 weeks before harvest) may increase fruit size as much as thinning done shortly after the June drop. With apples little work has been done to determine the effect on size, of thinning done at various times during the season. This report describes a series of experiments which have been conducted at this station during the past 5 years to determine the effects on apple size of thinning done at intervals during the growing season.

The first tests were made in 1931 on 18-year-old Oldenburg trees in the Gold Miller orchard in the eastern panhandle. Four or five trees were included in each treatment. Thinnings leaving fruit 4 to 6 inches apart were made on three dates at about 10-day intervals. In Table I are shown the per cent of fruit from each treatment which fell into three size classes together with average tree yield.

TABLE I—EFFECT OF TIME OF THINNING ON SIZE AND TOTAL YIELD OF OLDENBURG IN 1931

Date Thinned	Date Picked	Per Cent Less Than 2¼ Inches	Per Cent 2¼ to 2½ Inches	Per Cent Over 2½ Inches	Total Average Tree Yield (Bushels)
June 11–12..	July 28	3	26	71	9.2
	August 6	13	16	71	
June 22 ..	July 28	5	25	70	7.5
	August 6	22	13	65	
July 3.	July 28	3	16	81	8.5
	August 6	23	18	59	
Check— not thinned	July 28	1	46	53	11.0
	August 6	23	23	54	

There was a progressive increase in the per cent of fruit picked on July 28, the earlier the thinning. Thus, from trees thinned on June 11 to 12, 72.3 per cent were picked on July 28, from trees thinned June 22, 68 per cent, and from trees thinned July 3, 61.8 per cent. Only 49.6 per cent of the fruit was harvested from the check trees at that time. Color was better on fruit from the thinned than from the check trees. Early harvesting is important with early varieties such as Oldenburg as prices are generally higher at the beginning of the season.

A similar test was conducted on Golden Delicious in the Robinson orchard. When the fruit was harvested on October 12, it was graded into three sizes. The per cent falling into each size together with total yield are shown in Table II. An examination of these data indicates that the later thinnings gave as good or better results than did the early

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one. When average apple circumference gains are considered (Table III) the last thinning did not result in as high a per cent gain as the earlier thinnings.

TABLE II—EFFECT OF TIME OF THINNING ON SIZE AND TOTAL YIELDS OF GOLDEN DELICIOUS IN 1931

Time Thinned	Number Trees	Per Cent Less Than 2¼ Inches	Per Cent 2¼ to 2¾ Inches	Per Cent Over 2¾ Inches	Total Yield (Bushels)
June 13	12	9.9	59.4	30.7	88.4
July 14	12	4.8	57.0	38.2	94.5
August 14 . . .	12	4.5	54.8	40.7	91.1
Check— not thinned	12	15.2	71.2	13.6	84.3

TABLE III—AVERAGE CIRCUMFERENCE GAINS OF GOLDEN DELICIOUS APPLES THINNED AT DIFFERENT TIMES IN 1931

Time Thinned	Number Apples Measured	Circumference in Cm June 15	Per Cent Gain in Circumference			
			July 15	August 14	September 11	October 10
June 13	16	2.7	52	100	122	133
July 14	13	2.7	55	103	123	132
August 14 . . .	9	2.9	55	88	110	120
Check— not thinned	13	2.9	47	77	91	100

Experiments were also conducted at the Experiment Station orchard at Morgantown in 1932. Thinnings were made on June 1 and July 1 on 15-year-old Delicious trees using the branch unit method. From 100 to 176 apples were measured at each thinning with a final measurement at harvest time on October fourth, shown in Table IV.

TABLE IV—EFFECT OF TIME OF THINNING ON DIAMETER OF DELICIOUS IN 1932

Time of Thinning	Number of Apples Measured	Average Diameter of Apples (Mm)
July 13	53	64.70
August 1	55	63.60
September 1	51	63.43

A large number of apples fell during the course of the experiment which explains the small number remaining to be measured at the close. The apples, as will be noted, were progressively smaller from the early to the late thinning. Apples from all thinned limbs were measured at harvest as to per cent and intensity of color. No differences were observed that might be ascribed to time of thinning.

Thinning tests were continued in 1932² in a 20-year-old Grimes block where five trees each were thinned on June 2, July 1, August 1, and September 1. The crop was harvested on September 13 and sepa-

²Experiments so far described were conducted by Dr. Leif Verner when Assistant Horticulturist at University Experiment Farm, Kearneysville, W. Va.

rated into three sizes. A summary of the data is shown in Table V. From the standpoint of size of fruit, the thinnings made on June 1 and July 1 were better than those of later dates. It should be noted that 72 per cent of the fruit on the check trees was below $2\frac{1}{4}$ inches in diameter; distinctly smaller than from any thinning treatment.

TABLE V—EFFECT OF TIME OF THINNING ON SIZE AND TOTAL YIELD OF GRIMES IN 1932

Time Thinned	Per Cent Less Than $2\frac{1}{4}$ Inches	Per Cent $2\frac{1}{4}$ to 2 $\frac{3}{4}$ Inches	Per Cent Over $2\frac{3}{4}$ Inches	Total Yield (Bushels)
June 1	45.3	54.2	.5	20.5
July 1	29.8	68.2	2.0	22.2
August 1	64.2	35.8	0	15.9
September 1	54.6	45.4	0	17.2
Check— not thinned	72.1	27.5	.4	23.0

In 1933, 16-year-old Wealthy apple trees in the Station orchard at Morgantown were thinned at different times. It will be noted from Table VI that the fruits from the early thinning treatment were distinctly larger than from the later thinnings. There was no difference in size of fruit between the July 5 and July 31 treatments.

TABLE VI—EFFECT OF TIME OF THINNING ON SIZE AND YIELD OF WEALTHY IN 1933

Time of Thinning	Number of Trees	Per Cent of Drops	Per Cent Under $2\frac{1}{2}$ Inches	Per Cent $2\frac{1}{2}$ to 3 Inches	Per Cent Above 3 Inches	Average Total Tree Yield (Bushels)
June 5 .	6	14.6	2.0	40.8	42.6	6.27
July 5 . .	7	14	4.0	54.5	27.5	5.13
July 31 . .	6	13.1	5.3	54.6	27.0	5.41

More apples will be removed at the earlier thinnings so costs may be greater. In the Delicious experiment described above, 64 per cent of the apples were removed at the July 13 thinning, 51 per cent at the August 1 thinning, and 56 per cent at the September 1 thinning. Undoubtedly many apples were taken off at the first thinning that normally would have dropped later, for in the period from July 13 to August 1, 18 per cent of the apples fell from limbs that were to be thinned August 1. Since the aim is to thin to a specified distance apart, late thinning, however, is generally heavier because of larger fruit size; partly offsetting any drop that may have occurred prior to the thinning.

DISCUSSION

In contrast to results from earlier thinning experiments with peaches, these studies with apples indicate that the earlier the thinning the larger will be size of fruit at harvest time. The important advantages of late over early thinning still must be considered and may outweigh other factors, particularly in regions of mid-summer hail storms.

A second advantage of early thinning over late thinning must also be considered because of the possibility that it may promote annual cropping in biennial bearing varieties such as York, Wealthy, Grimes

and Baldwin. It has been shown (2) that with trees in good vigor severe early thinning tends to bring about annual bearing.

From the practical standpoint, early thinning may be practiced with biennially bearing varieties and later thinning may be performed on other varieties as time allows. As a rule, orchardists cannot get all their thinning done in June. It also seems that inevitably growers do not thin severely enough when the operation is performed early in the season. Acceptable commercial size for each variety must also be considered since early thinning may often result in oversized apples.

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Some Nutritional Factors Involved in Fruit Setting in the Apple

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ABSTRACT

This paper will be published in full in the *Journal of Agricultural Research*.

THE ability of a well pollinated flower to hold its fruit past the June drop under adverse climatic conditions is frequently of economic importance to the fruit grower. Students of pollination and of fruit bud formation have repeatedly emphasized nutritional factors associated with vigor as of prime importance for set of fruit after pollination. Howlett has called attention to the relatively large amount of materials in fruits and flowers that drop. Murneek has emphasized the volume of nutrients that flow into and through spurs that are setting fruits. Wiggans and Chandler have called attention to the greater sap density associated with fruitfulness. Heinicke has emphasized spur size, spur vigor, conducting tissue, seed count, water relations and similar factors associated with the ability of a spur to hold its fruit. Numerous observations have been reported indicating that young vigorous trees fail to set as high a percentage of flowering spurs as do older trees. Heinicke and others have reported that both early ringing and nitrogen applications may increase the set of fruit on the same tree.

The attempt reported here was to vary as widely as possible the percentage of blossoming spurs that would set fruit and to determine what if any differences in carbohydrate and nitrogen composition might accompany such variation in set. Of a number of methods tried, ringing branches of young trees at about blooming time gave widest variations in set. On April 28 and 29, 1931, over 100 such branches were ringed, each with a comparable check on the same Grimes Golden tree. Full bloom occurred on May 1 and 3. The current season's spur growth was sampled on four successive dates at 5-, 6- and 7-day intervals, namely, on May 14, 19 and 25 and on June 2. Sucrose reducing substances as glucose, starch, total nitrogen, and alcohol soluble nitrogen were determined. Percentage fruit set was determined in July after the June drop.

The percentage of spurs that held one or more fruits past the June drop was increased from 37.5 per cent on the check branches to 78.7 per cent on ringed branches on trees from which spurs were sampled. Sample branches were not included. Ringing or scoring at various dates up to May 18 increased the set from 43.6 per cent on checks to 80.9 per cent on ringed or scored branches. That weak devitalized spurs might be avoided, only spurs carrying flowers or fruits were sampled for chemical analysis. It is obvious that each of these classes of spurs would more nearly approach the average composition of the two than would have been the case had it been possible to determine in advance just which spur would or would not drop the fruit. The results of analyses show in general a higher dry weight, lower moisture and higher carbohydrate content and a somewhat lower nitrogen content in spurs from ringed branches than those from checks.

Harvey and Murneek, Howlett, Dutton and others have emphasized the effect of spur defoliation and injury on fruit set. It is interesting to note that the spur leaves were much higher in carbohydrate content on ringed branches. It seems evident that the function of these leaves in close proximity to the delicate fruit embryo may play an important part in maintaining an uninterrupted supply of food materials that in turn may enable the spur to hold its fruit.

To summarize: ringing branches just prior to blooming doubled the percentage of blossoming spurs that held their fruits on 8-year-old Grimes Golden trees. The heavier set of fruit was accompanied by a higher carbohydrate content and a somewhat lower nitrogen content both in soluble and alcohol soluble nitrogen. This seems to confirm the conclusions of others that fruit setting is dependent upon a high level of food supply both carbon and nitrogen.

Some Anatomical Aspects of Apple Flower and Fruit Abscission

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THE dropping of McIntosh fruits before they are well colored or before they can be harvested after attaining the desired color, is recognized as a serious defect of this variety. It is in fact sufficiently important to limit the acreage of this variety that can be grown by any one orchardist. Among commercial varieties grown in New York, Wealthy also gives some trouble in this regard, but the varieties Rome, Northern Spy, and Cortland may hang on the tree even after they are over-mature for best keeping quality.

The present study aims to gain a better understanding of the structural basis of abscission as ground work for further study of the physiological factors involved in the dropping of the fruit. The purpose of this paper is to describe the structure of the abscission zone of several

varieties and some of the details of the abscission process of the flowers and fruit without considering the physiology of abscission or the effect of environment on the formation of the abscission layer.

The ability of the fruit of a variety to hang on the tree after it has matured is in some cases associated with the length of the pedicel. Thus, a long, flexible pedicel permits the apple to swing back and forth without strain on the point of attachment. This condition is found in Rome Beauty and the Golden Delicious. Long pendulous spurs such as are found in Twenty Ounce and also in the Rome have the same effect. McIntosh on the other hand has a noticeably short stiff pedicel attached to a short stiff spur, a condition which is certainly in part responsible for the drop-

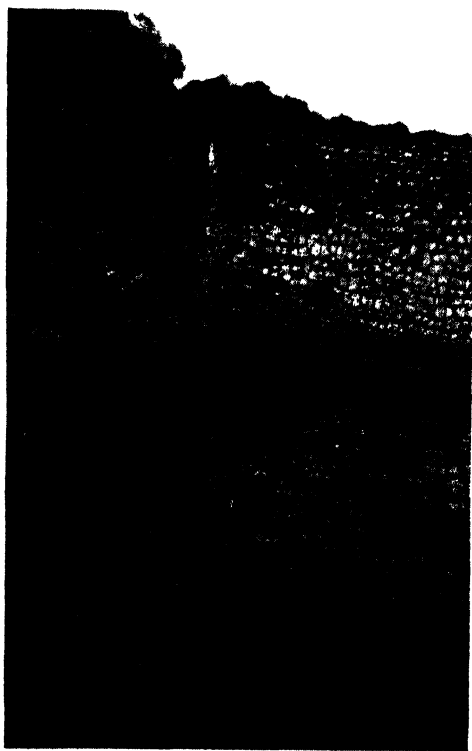


FIG. 1. Abscission layer cutting through base of pedicel of flower. There is very little hard tissue in the pedicel at this stage of development.

ping of the fruit. The nature of the abscission zone or layer is also without question of some importance in determining the readiness with which the mature fruits are shed.

The fruits of apple varieties vary in the ease with which they are separated from the tree from season to season and to a certain extent there is variation correlated with environmental factors. Thus it has been observed that McIntosh fruits borne on trees which have been recently moved and are somewhat under-vigorous, separate from the spurs with much more difficulty than on trees that have not been moved. With other normal trees there seems to be little correlation of the ease of separation and early dropping, with application of fertilizers, mulching treatment, or moisture supply except as these may influence the maturity of the fruit.

The abscission of the apple flower or fruit, in the morphological sense, is the cutting away of a modified branch or axis. Such abscission may occur at petal fall, or early in the development of the fruit, or late in the season, at harvest. In early season abscission the abscission layer cuts through the parenchymatous tissues and the pedicel is cut off. The vascular tissue of the pedicel and cluster base at this stage is undifferentiated procambium with occasional protoxylem strands. Sclerenchyma has not yet formed. Ordinarily the abscission layer cuts through the base of the pedicel where it joins the cluster base. Such a condition is shown in Fig. 1. In other cases the pedicel may be cut off at some little distance from its point of attachment. In this early season abscission there is evidently cell division in the layer of cells through which separation takes place. Such division is indicated in Fig. 2. By the removal of leaves from the cluster base, Heinicke (1) has shown that the abscission layer will cut across the cluster base itself without reference to the attachment of the pedicel so long as cluster base tissues are immature and mostly unlignified. This is particularly true of pears which have a cluster base much longer than that found in the apple.

In order to understand the modifications found in the abscission zone at harvest an understanding of normal pedicel structure is necessary. This consists of a central pith which is for the most part made up of stone cells.

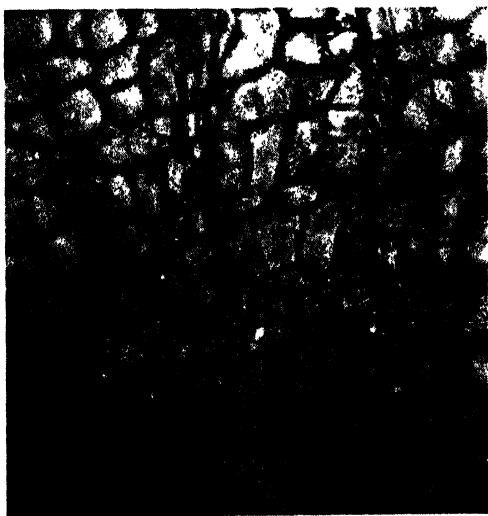


FIG. 2. A part of the abscission layer shown in Fig. 1, at higher magnification. The arrangement of the cells indicates probable cell division in the abscission layer.

The pith area is surrounded by a ring of well developed xylem mostly of secondary origin, outside which is a well defined ring of phloem surrounded first by a ring of well developed elongate fibers and second by irregularly formed groups of stone cells. The outer layers are made up of cortical parenchyma, some collenchyma, and normal epidermis. The whole structure is very strong and tough for its size. This normal pedicel structure is shown in Fig. 3.

The modifications of this normal pedicel structure which occur in



FIG. 3. Structure of pedicel of mature fruit of variety Delicious in cross section. The figure shows a central core of pith encased by concentric rings of xylem, phloem, fibers and stone cells.

the abscission zone are as follows: (a) A reduction in the diameter of the pedicel at the point of its junction with the cluster base. This constriction is relatively deep in the variety McIntosh but much more shallow or perhaps wanting in the variety Rome. (b) The presence of abundant specialized collenchyma immediately underneath this constriction extending through the area occupied by fibers and stone cells in the normal pedicel. (c) The reduction in amount or absence of sclerenchyma in what would be the cortical region of the pedicel. (d) The reduction of the number of fibers and vessels of the vascular cylinder as compared with that found in the pedicel and their replacement by parenchyma. (e) The modification of the vessel from the normal porous type with round pits to the scalariform type with scalariform pits. (f) The modification of epidermal cells in the constriction about the abscission zone to form cushions of elongate cells which apparently separate readily in abscission (Fig. 4). The structure of the abscission zone is shown in the photomicrograph, Fig. 5. All of the modifications are such as would weaken the zone of tissue and make possible the formation of an abscission layer cutting through soft tissues.

The abscission zone is somewhat indefinite in its limits usually extending for about half a millimeter or less and merging on one side with the pedicel and on the other with the cluster base. The cluster base is a modified axis differing from normal apple twig structure in

having a very large pith and a weakly developed woody cylinder that is much broken by the branch gaps left by the branch traces passing outward to the other flowers or fruits that made up the original flower cluster. At harvest time the scars left by the abscission of these flowers are covered with a periderm layer. The cortical region of the cluster base contains abundant fibers and stone cells. Because of the branch gaps and leaf trace gaps, however, there is no continuous sheath of xylem and sclerenchyma comparable to that found in the pedicel. Abscission does not take place



FIG. 4. Modified epidermal cells at point of constriction at base of pedicel. It is through these cells that abscission starts. The tissues below are thick walled collenchyma.



FIG. 5. Longitudinal section of abscission zone at base of McIntosh pedicel showing end of sclerenchyma cylinder S, constriction at base of pedicel, specialized collenchyma of abscission zone C and abscission layer A.

through the cluster base at the time the fruit is shed. In some varieties under some conditions, parts of the cluster base may be cut off later by abscission through the branch gaps.

As stated above, the abscission zone is plainly indicated by its modified structure. The abscission layer, or layer of cells through which abscission takes place is obscure. There is apparently no preformed layer of specialized cells extending through the whole abscission zone as is found in leaf bases before leaf fall though such a layer does exist in some of the harder tissues of the abscission zone (Fig. 6).



FIG. 6. Part of abscission zone showing layer of soft tissue extending across the central core of sclerenchyma.

In the material examined, with very few exceptions, it was possible to locate a layer of living cells extending as a sheet of tissue through the core of stone cells in the pith region of the abscission zone in plane of fracture. In most cases this was only one or two layers of cells thick but in others seven or eight. At the time of shedding of the fruit the plane of fracture is extended from this layer through the vascular tissues and collenchyma. In these tissues no preformed abscission layer was observed with certainty though with fruits that were separating easily it is possible in some specimens to follow the probable line of abscission by the slightly different staining reactions of the cells along the line of abscission.

In the abscission process at harvest time there is apparently no proliferation of cells in the abscission layer as is found in the early season abscission but rather, a change in the chemical nature of the cell walls which permits easy fracture. Before maturity the tissues of the abscission zone resist fracture and must be torn apart leaving a rough surface as indicated in Fig. 7. The chemical change which causes the collenchyma to split easily apparently takes place very rapidly in some varieties and more slowly in others accounting in part for varietal differences in abscission.

In the natural separation of the fruit from the cluster base the split occurs through the modified cells of the epidermis at the base of the pedicel, passes through the living collenchyma and vascular tissues of the abscission zone and through the abscission layer of the sclerenchyma in the pith area. The relatively few xylem elements are apparently ruptured mechanically. Aggregations of stone cells projecting in the abscission zone from the pedicel, that are not cut through by an abscission layer, are pulled out of the soft parenchyma tissue of the abscission zone and shed with the pedicel.

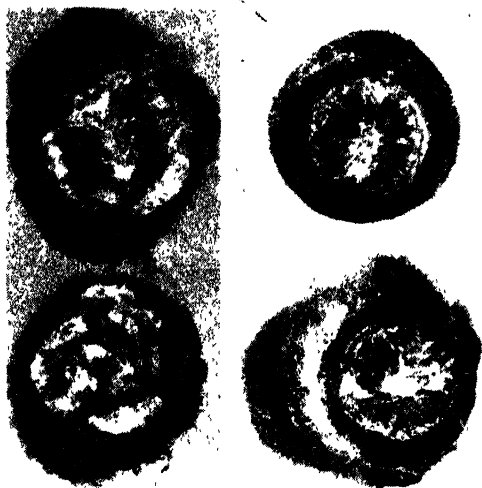


FIG. 7. (Left)—Rough surface of tissues of abscission zone torn apart before the abscission layer had been formed. (Right)—Relatively smooth surface of tissues of abscission zone cut through by abscission layer.

The line of fracture is smooth through the collenchyma and somewhat rough through vascular tissue and sclerenchyma as indicated by Fig. 7.

In comparing the abscission zone of the McIntosh with that of varieties such as Rome, Spy, and Delicious, which do not drop so easily, a number of differences of possible significance were observed. The abscission zone of McIntosh is more clearly defined than that of the other varieties examined and is relatively free from sclerenchyma tissues (Fig. 5). In McIntosh (Fig. 8) there are usually no fibers and only a few stone cells in the abscission zone, whereas in the specimens of Northern Spy (Fig. 9) and Delicious observed there are groups of both extending through it. Another difference is the cross sectional area of the abscission zone. In McIntosh the constriction is relatively deep, resulting in a small cross sectional area, whereas in Rome and to a less degree in Spy, the constriction is slight or even wanting and the cross sectional area of the abscission zone is greater. As compared with Rome and Spy, the dropping of McIntosh is increased by the fact that the stem of McIntosh is relatively short and stiff so that it transmits a greater strain on the soft abscission zone when there is any movement of the fruit. Rome and Spy have long stems and long pendulous spurs so that movement of the fruit does not put a direct strain on the abscission zone. There are also without much question chemical and physiological differences which are in part responsible for the more rapid changes in ease of separation that are to be observed in McIntosh as compared with Spy, Rome, and Delicious.



FIG. 8. Cross section through abscission zone at base of McIntosh pedicel. The tissues are mostly modified thick walled collenchyma. The only sclerenchyma is made up of stone cells in the central pith area. Compare with Fig. 9.



FIG. 9. Cross section of abscission zone at base of pedicel of Northern Spy. The light colored areas are sclerenchyma tissues which are more abundant than in McIntosh. Compare with Fig. 8.

A comparison of the abscission zones of fruits from McIntosh trees that showed marked differences in the time of dropping their fruit or differences in ease of separation did not bring out any marked structural differences. These comparisons included trees that had been moved recently and those that had not, trees with high nitrate and trees with low nitrate, and trees with heavy mulch and in sod. There was an indication that the tissues of cluster base, pedicel and abscission zone of the moved trees were harder than in the others. This condition would be expected as it is generally true that plants making slow growth and probably with a low nitrate and high carbohydrate ratio produce harder tissues with more sclerenchyma than more rapidly growing plants. The effect of this condition might well be to produce a stronger abscission zone as well as affect the physiology of abscission. A more extensive study of trees showing differences in abscission is needed to determine what these effects may be.

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A Rapid Method for Determining Soluble Nitrogen and Phosphate Phosphorus in Woody Tissue¹

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RECENT studies by Emmert (1) have shown a high correlation to exist between growth and fruitfulness of beans and tomatoes and the content of soluble nitrogen and phosphate phosphorus in the conducting tissues of these plants. The results obtained by Emmert with vegetable plants suggested the possibility that similar relationships may exist with tree fruits and clearly indicated the need for a rapid method for determining these compounds in woody tissue.

MATERIALS AND METHOD

The methods of analysis and extraction herein described are adaptations, with necessary modification, of the procedure by Emmert (2, 3) and are easy and rapid.

Sampling:—Any sections of shoot, twig, root or spur growth may be analyzed, but for the studies referred to in this paper, shoots arising from terminal buds on main branches were used. Shoots of approximately the same length and diameter should be chosen and the samples duplicated or triplicated for the tests. These should be taken from trees receiving uniform treatment. The leaves are removed immediately and the samples wrapped in a damp cloth to be brought to the laboratory for weighing.

Extraction:—A 1- or 2-gram portion from the apical third of the terminal shoot was used. The weighed sample was cut into thin disks with a pair of sharp pruning shears and placed in a mortar. Approximately .5 grams of phosphorus-free charcoal (4) was added and 3 or 4 grams of sharp sand that had been washed and ignited. An accurately measured quantity, 10 cc or 20 cc² of 2 per cent acetic acid was added and the sample finely ground. The extract was filtered into a 25 cc test tube. It contains both the soluble nitrogen and phosphate phosphorus.

Soluble Nitrogen:—To .5 cc of the extract in a 25 cc test tube a little sodium chlorate about the size of a grain of wheat was added and 1 cc of fuming sulfuric acid (15 per cent SO_3) was run in rapidly so that the solution boiled vigorously and complete oxidation of organic matter was accomplished. The chlorine evolved by the reaction must be cleared from the tube by shaking and blowing across the top. As soon as the solution was perfectly clear, .5 cc of phenoldisulfonic acid was added and mixed well. This was allowed to stand for about a minute and approximately 5 cc of water was added and the solution again mixed well. Neutralization of the acid solution and the development of the yellow nitrogen color was accomplished by adding 40 per cent sodium hydroxide solution from a pipette until the maximum yellow

¹The investigation reported in this paper is in connection with a project of the Kentucky Agricultural Experiment Station and is published by permission of the Director.

²Mature wood tissue absorbs and holds the extraction liquid so that 10 cc of acetic acid on a two-gram sample gives hardly enough extract for the determination of both nitrogen and phosphorus.

color developed. The solution was made to 20 cc volume with water and compared with a standard in a colorimeter. The standard used contained .0025 mg of nitrogen as NO_3 in 1 cc of the solution.

Phosphate Phosphorus.—To 3, 4 or 5 cc of the extract (4), depending on the amount available, a few cc's of water, 2 cc of 2.5 per cent solution of ammonium molybdate in 5 normal sulfuric acid and 1 cc of 1-2-4 aminonaphthol sulfonic acid reagent were added. The volume was made to 20 cc with water and after standing a short time to allow the full blue color to develop, the amount of phosphorus was determined colorimetrically with a standard containing .002 mg of phosphorus as PO_4 in each cc of the solution.

RESULTS

The portion of shoot giving the higher analysis was considered a more accurate measure of the quantities of these materials that were available for anabolic processes. The percentage of nitrogen was more variable than that of phosphorus in wood of any age and the phosphorus content of the wood varied less than the nitrogen content from the tip to the basal portion of the current season's shoots. The soluble nitrogen content of shoots was found to be increasingly lower from the tip to the basal portions, while phosphate phosphorus varied less in this respect. Table I gives the average of five sets of independent determinations made on different portions of Winesap apple and Elberta peach shoots in May, 1935. The results are given in parts per million of green tissue.

TABLE I.—SOLUBLE NITROGEN AND PHOSPHATE PHOSPHORUS IN DIFFERENT PORTIONS OF APPLE AND PEACH SHOOTS

Part Used	Winesap				Elberta			
	N	P E	P	P E.	N	P E	P	P E.
Apical third	116	±1.11	73	±.69	136	±1.39	106	±1.41
Median third	92	±1.39	74	±.69	106	±2.32	103	±1.54
Basal third.	54	±.69	74	±.69	89	±1.83	98	±.95

Tests of leaves showed no correlation between the soluble nitrogen content and the conditions under which the trees were growing. It appears that the rapid growth and utilization of the nutrients makes it inadvisable to use leaves for analysis.

As a means of testing the accuracy of the method of analysis, several determinations were made for soluble nitrogen from a single extract and for phosphate phosphorus from a single extract. These determinations were made on both apple and peach tissue and the results are shown in Table II. Because of the larger quantity of extract required for a phosphorus determination, fewer tests from a single extract could be made. Also, for the same reason, the nitrogen and phosphorus determinations were not made from the same single extract.

In Table II the averages for soluble nitrogen for both apples and peaches were obtained from 10 determinations and for phosphate phosphorus from four determinations.

TABLE II—SOLUBLE NITROGEN AND PHOSPHATE PHOSPHORUS
DETERMINATIONS FROM SINGLE EXTRACTS OF APPLE AND
PEACH TISSUE (RESULTS GIVEN IN PARTS PER MILLION
OF GREEN TISSUE)

Apple				Peach			
N	Per Cent P. E.	P	Per Cent P. E.	N	Per Cent P. E.	p	Per Cent P. E.
119±1.14	.96	87±.56	.64	149±1.30	.87	100±1.12	1.13

Complete results of soluble nitrogen and phosphate phosphorus determinations covering a period of approximately 1 year on Winesap apples and Elberta peaches are given in a recent bulletin from the Kentucky Experiment Station (6).

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Nitrogen Content and Growth Response From Fall and Spring Fertilizer Applications to Apple Trees¹

By GEO. E. SMITH, *University of Missouri, Columbia, Mo.*

IN view of the increasing interest in fall fertilization and greater use of calcium cyanamid for apples in Missouri, the present study was started in the fall of 1934 to compare the relative value of sodium nitrate, ammonium sulfate and calcium cyanamid when applied to mature apple trees at different times in the fall and in the spring.

Fifteen year old Golden Delicious and Gano trees growing in heavy blue grass sod on loess soil have been given 1 pound of nitrogen in the three forms, broadcast on the surface beneath the branches. The first fall applications were made from September 15 to October 1, while the trees were still quite active and the leaves green, and the second after November 1, when the leaves were beginning to fall. The first spring application was made from 6 to 8 weeks and the second from 2 to 3 weeks before bloom. The spring of 1935 was wet, conditions were favorable for growth and the trees bore a heavy crop of fruit. The spring of 1936 was dry, and because of a strong alternate bearing habit, the Gano trees had little fruit and the Golden Delicious none at all. Samples of various portions of the tree tops have been collected throughout the year and total nitrogen determinations made on the dry tissue. Growth measurements have been made on the twigs in both years.

The growth and nitrogen percentage of the trees reflect the conclusions made earlier (4) that soil moisture immediately following the fertilizer application has a marked effect on the utilization of cyanamid. In the fall of both 1934 and 1935 when the fertilizer was applied early the weather was dry and remained so for some time. On the later applications precipitation was heavy. In both years the nitrogen percentages of the tree tops and nitrogen recovery from cyanamid during the following spring and summer were greater from the late fall application with the more moist conditions. Table I gives the quantity of nitrogen in the blossoms and young fruits. Although these differences are not great, the same relationship exists for all tissues analyzed.

TABLE I—MG. N IN BLOSSOMS AND FRUITS PER SPUR. CYANAMID APPLIED IN FALL OF 1934 AND SPRING OF 1935 (SAMPLES COLLECTED IN 1935)

Time of Application	April 26 Blossoms	May 17 Fruit	June 22 Fruit
Check	4.7	7.5	20.3
Early Fall (1934)	5.3	11.1	27.0
Late Fall (1934)	5.9	11.6	31.6
Early Spring (1935)	5.4	10.7	25.5
Late Spring (1935)	5.5	9.1	27.4

If the figures for the spring applications of 1935, which was moist, are compared with those of 1936, which was extremely dry, it is noted

¹Contribution from the Department of Horticulture Missouri Agricultural Experiment Station Journal Series No. 488.

that the same contrast exists between the two springs as is found between the two applications of one fall. The figures given in Table II of the nitrogen percentage of twig leaves in 1935 indicate that under moist conditions when cyanamid was applied 3 weeks before bloom it gave as great nitrogen percentage as ammonium sulfate and sodium nitrate applied at the same time. On the other hand with the dry spring of 1936, the results are as would be expected with a smaller percentage of nitrogen in the cyanamid treated trees as is shown in Table III. The recovery of nitrogen from cyanamid as compared to sodium nitrate was somewhat lower in 1936 than in 1935. However, the difference between cyanamid and ammonium sulfate in 1936 was small.

TABLE II—PERCENTAGE NITROGEN OF DRY TWIG LEAVES. FERTILIZERS APPLIED 3 WEEKS BEFORE BLOOM (1935)

Material	April 26 (Full bloom)	May 17	June 22	September 14
Check	2.96	1.94	1.98	1.64
Cyanamid	3.46	2.31	2.16	1.78
Ammonium Sulfate	3.44	2.50	2.10	1.76
Sodium Nitrate	3.59	2.42	2.18	1.77

TABLE III—PERCENTAGE NITROGEN OF DRY TWIG LEAVES. FERTILIZERS APPLIED 3 WEEKS BEFORE BLOOM (1936)

Treatment	April 18	May 1	May 21	June 12	August 5
Check	2.92	2.76	1.60	1.54	1.20
Cyanamid	3.40	3.08	1.98	1.61	1.30
Ammonium Sulfate	3.56	3.05	2.06	1.90	1.30
Sodium Nitrate	3.56	3.34	2.33	2.12	1.34

Disregarding the cyanamid blocks due to abnormalities introduced by moisture, a consideration of the responses from spring and fall applications of sodium nitrate and ammonium sulfate indicates that the fall applications have been most efficiently utilized. Even on the fall applications of sodium nitrate where much leaching occurred, the figures for nitrogen percentage and recovery are as great as for the corresponding spring applications. The figures given in Table IV indicate that recovery has been as great for fall as for spring fertilizations.

TABLE IV—MG.-N IN LEAVES ON ONE TWIG. SODIUM NITRATE APPLIED FALL OF 1934 AND SPRING 1935. (SAMPLES TAKEN SPRING AND SUMMER 1935.) (AVERAGE 40 TWIGS)

Time of Application	April 26	May 17	June 22	September 14
Check	30.2	67.5	106.5	81.2
Early Fall	37.5	110.1	160.0	107.6
Late Fall	38.2	99.0	141.0	92.7
Early Spring	31.8	99.8	134.7	96.9
Late Spring	36.3	90.4	125.7	102.0

In 1935 from 25 to 30 twigs were cut from each of the eight Golden Delicious trees of each block, brought into the laboratory, dried, and length and weight measurements made. In 1936, length and diameter

(middle of twig between nodes) measurements were made in the field on the same number of twigs. These results are presented in Table V.

TABLE V—AVERAGE LENGTH, WEIGHT, AND DIAMETER OF TWIGS FROM GOLDEN DELICIOUS TREES RECEIVING FERTILIZER IN FALLS OF 1934 AND 1935, AND SPRINGS OF 1935 AND 1936

Material	Average Length (Cms)		Average Weight (Grams) 1935	Average Diameter (Mms) 1936
	1935	1936		
Check				
.....	21.3±.29	12.5±.20	1.38	2.92±.009
Early Fall				
Ammonium Sulfate ...	29.8±.29	19.6±.21	2.47	3.14±.007
Cyanamid	29.1±.27	17.2±.15	2.17	3.18±.008
Sodium Nitrate	26.8±.26	19.4±.23	1.94	3.20±.008
Late Fall				
Ammonium Sulfate . .	28.0±.34	17.2±.25	2.22	3.06±.008
Cyanamid	30.5±.30	19.6±.22	2.24	3.22±.008
Sodium Nitrate	26.5±.22	20.6±.17	1.90	3.21±.009
Early Spring				
Ammonium Sulfate . .	21.3±.31	17.7±.28	1.18	3.12±.009
Cyanamid	26.8±.35	18.7±.40	1.86	3.18±.007
Sodium Nitrate	25.7±.43	19.1±.24	1.81	3.20±.009
Late Spring				
Ammonium Sulfate . .	27.8±.33	15.6±.23	2.14	3.11±.008
Cyanamid	28.4±.44	16.2±.36	2.20	3.08±.007
Sodium Nitrate	25.1±.31	16.1±.34	1.65	3.12±.009

In 1935, although the trees bore a heavy crop, the growth was much greater than in 1936, with a deficiency of moisture and no crop. Considering all the length measurements, it appears that fall applications of all three materials have given as good if not greater growth than the spring applications. In 1935 cyanamid applied late in the spring gave equally good if not better results than the two other materials, which agrees with the nitrogen recovery data in Table II. With the deficiency of moisture in 1936, the length of growth on the late spring application of all materials was much reduced and about the same; however, the diameter growth of the cyanamid block was somewhat smaller, indicating less growth later in the season. Considering the four cyanamid applications, the late fall treatment has in both years given the greatest growth. In 1935 it appeared that the fall applications of nitrate gave smaller growth than ammonium sulfate and cyanamid, but in 1936 this difference did not hold. The figures for early spring ammonium sulfate in 1935 should be disregarded as it is evident that they are in error. The average of probable errors for length of growth on all fall fertilized blocks is $\pm .28$ cm and $\pm .33$ cm for spring. This would indicate that fall fertilization gives a greater uniformity of growth.

The growth and nitrogen percentage of the various blocks does not agree with the results of others (5, 2, 3), who obtained much superior

results from sodium nitrate when applied in the spring than in the fall, and inferior results with ammonium sulfate and cyanamid. Since their differences decreased somewhat after the first year, it is possible that soil differences might account for the variation between their results and the ones presented here. From data not included and the findings of others (1, 5), it is evident that nitrogen fertilizers applied in the fall are rapidly absorbed by the roots and held there until growth starts in the spring. Under these conditions, it appears that fall fertilizer applications are as efficient as spring applications and that identical results should be secured from fall and spring fertilization if moisture conditions are favorable. Under Missouri conditions where spring moisture is so variable, it would seem advisable to shift fertilization to the fall. In no case has any injurious effect been obtained with cyanamid, and it has given very good results when applied in the spring if there was an abundance of moisture. In view of the response of the trees with different moisture conditions following the application of cyanamid it seems highly important to make cyanamid applications during rainy periods or where possible to work it into the soil.

The author wishes to acknowledge the help of Dr. A. E. Murneek under whose direction this work has been done, and to thank the American Cyanamid Company for support in the form of a fellowship grant.

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Responses of Young Apple Trees to Nutrient Deficiencies

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ABSTRACT

This material will be published as a bulletin of the New Jersey Agricultural Experiment Station.

ONE-YEAR-OLD Blaxtayan root-grafted apple trees were grown in sand cultures in six different nutrient treatments: (a) A complete nutrient solution in which all essential elements were supplied in proportions favorable to good growth, and five other series of treatments each containing all essential elements except one, *i.e.* (b) no calcium; (c) no magnesium; (d) no nitrogen; (e) no phosphorus, and (f) no potassium.

Tree responses to the respective deficiencies were studied in detail to note the effects upon composition, structure, external appearance and growth characteristics.

No Calcium Treatment:—A deficiency of calcium resulted in a very marked stunting of growth and death of stem and root tips. Although an abundance of insoluble calcium was present in the old roots and in the base of the old stem, this was not reutilized in sufficient amounts to meet the requirements of the trees. No leaf discolorations or spotting characteristic of calcium deficiency developed during the first season, but they did appear early in the second season.

No Magnesium Treatment:—Magnesium was freely reutilized by young apple trees but the demand for this element by the plant was constant. Hence, when magnesium was withheld, a characteristic type of leaf injury soon developed. The affected leaves soon fell from the trees. The current stems of trees lacking magnesium were very low in carbohydrates, small in diameter, and deficient in woodiness. The roots of these trees branched very little, were characteristically small in diameter, and soon lost their cortex.

No Nitrogen Treatment:—Lack of an external supply of nitrogen was associated with an early appearance of yellowish-green blades and a reddening of veins of lower leaves. Later the upper leaves exhibited this condition and all leaves assumed an upright position, with petioles forming narrow angles with the stem. There was no conspicuous marking or spotting of the foliage. Carbohydrates accumulated in high concentration. Cambial activity was very limited and ceased early in the season, resulting in short stems of small diameter. Root growth was extensive, woody, and abnormally slender.

No Phosphorus Treatment:—In the early stages, a deficiency of phosphorus resulted in growth responses which were very similar to those described for trees deficient in nitrogen. Carbohydrates accumulated in roots and tops. The upper leaves remained dark green with mid-ribs, veins and petioles definitely tinged with purplish-red. The stem growth a few inches behind the terminal became more slender as the season progressed. After 4 months, these trees became very low

in starch and proteins and high in sugars, stem growth was very slender, the new leaves were very small, thin, dark green and tinged with purplish red.

No Potassium Treatment:—Potassium was freely reutilized by apple trees and a lack of an external supply of the element caused no very marked effects upon growth for several weeks. In time, however, the lack of potassium limited the capacity of the trees to synthesize proteins and, in turn, carbohydrates accumulated in roots and tops. As the deficiency of potassium became more severe, there was growth in length but little increase in diameter. The potassium depleted leaves at this time began to exhibit a marginal leaf scorch. This was followed by a gradual decrease in carbohydrates; new leaves were smaller and thinner, but exhibited a normal green color.

The Effect of Pruning and Nitrating Upon Apple Tree Performance

By M. J. DORSEY, *University of Illinois, Urbana, Ill.*

ABSTRACT

IN this series of specialized tree treatments an attempt was made to determine how effective such practices as pruning, nitrating and mulching might be in controlling the terminal fruiting variety, Ben Davis. The crop for a 7-year period was graded according to size and color under each treatment and the bloom for each tree each season during the period was charted for the eight sections of the tree, that is the upper and lower quarters. Production was heavy but the alternate bearing habit was not corrected by these treatments when thinning was omitted.

Biennial Bearing of McIntosh¹

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PROBABLY no other apple variety bears more regularly than the McIntosh. Nevertheless, biennial bearing in this variety is known. There has been a tendency in the past to ascribe it to lack of vigor. On the other hand, rather striking evidence has been presented recently which seems to indicate that the set of fruit early in the season may be of even greater importance than vigor of growth in determining regularity of bearing. Thus, in 1932 Auchter and Schrader reported that in the Shenandoah Valley mature trees of the York Imperial variety which sets heavily, bore biennially irrespective of whether they were making a terminal shoot growth of 4½ inches under poor culture or one of 11 inches with heavy fertilization and severe pruning. Both lots bore successively only when frost destroyed a considerable proportion of the blossoms. McCormick in Washington succeeded in making Yellow Newton and Ortley blossom fairly regularly and produce good crops 4 years in succession by thinning the blossom clusters and thus reducing the set prior to the June drop.

Both these experiences seem to indicate that a heavy set is at least a contributory cause of biennial bearing. Biennial varieties forced to set fruit lightly tend to become annual producers. An experience at the University of New Hampshire contributes further evidence. In 1932, a severe frost almost completely destroyed the flowers on a young and vigorous block of McIntosh trees which had been producing annually. The following year on account of excessive blossoming and favorable weather during the blossom period, the fruit set very heavily. Annual production per tree in this orchard together with measurements of shoot growth for those seasons for which it is available are shown in Table I.

TABLE I—PRODUCTION AND SHOOT GROWTH IN 60 MCINTOSH TREES
PLANTED IN 1919, UNIVERSITY OF NEW HAMPSHIRE

Year	Average Annual Yield per Tree (Bushels)	Average Annual Shoot Growth (Inches)
1927.	0.8	—
1928.	0.7	—
1929.	3.4	—
1930.	4.0	—
1931.	6.3	12.2
1932.	0.8 (frost)	9.7
1933.	14.4	13.9
1934.	2.0	5.5 (Winter injured)
1935.	13.0	8.0
1936.	3.6	—

There is clearly a period of annual production ending in 1931, and followed by an abrupt transition to biennial bearing. The lack of crop in 1932 is due to frost rather than to lack of fruit buds, but the trees had

¹Scientific Contribution 56 of the University of New Hampshire.

rather yellowish foliage and a high per cent of the spurs formed fruit buds as is typical in the "off" year. Fruit bud formation in 1933 seems to have been the crucial point determining whether the trees were to remain biennial or resume annual bearing. Following a heavy set, a large crop was produced, and very few fruit buds were formed as is typical in the "on" year. Just as a light set caused the typically biennial varieties to produce regularly, so a heavy set has established the biennial habit in the normally annual bearing McIntosh. The rather limited data on terminal shoot growth, indicate that the transition in 1932 and 1933 from annual to biennial bearing took place in spite of vigorous growth. There is a distinct drop in shoot growth beginning in 1934, which seems most logically explained as due to extreme cold of the preceding winter. Although these trees seemed practically uninjured, there was some browning of the pith near the ends of the branches. However, there is no evidence that the poor crop of 1934 was due to winter-killing of blossom buds.

In the spring of 1935, tests were inaugurated with some slightly more mature McIntosh trees adjacent to and similar to those mentioned above, to determine whether this biennial bearing habit can be overcome by thinning. In each of eight blocks, the fruit on one tree was thinned within 3 weeks of the blossom period to leave approximately one apple to every 50 leaves not counting small primary spur leaves or leaves on terminal shoots. Another tree in each block was similarly thinned about 6 weeks after blossoming, a third on August 10th, 9 weeks after blossoming, and the fourth was left unthinned.

The results of the thinning on the crop of 1935 are shown in Table II. All treatments reduced the yield but improved the size of the fruit, its color, and without doubt its market value. The unthinned trees produced by far the largest yield, but much of the fruit was under 2½ inches in diameter. Usually it does not pay to thin this variety because medium sized fruit is most desirable for the market. It does seem worth while in the case of distinctly overloaded tree like these.

TABLE II—EFFECT OF THINNING MCINTOSH TO 1 FRUIT TO 50 SPUR LEAVES ON THE CROP OF THE CURRENT SEASON

Date of Thinning	Days After Bloom	Number of Trees*	Average Yield per Tree (Pounds)	Average Diameter of Fruit (Inches)	Average Per Cent of Surface Colored Red
June 20	21	8	479	2-12/16	68
July 15	36	6	462	2-11/16	64
August 10	62	7	390	2-9/16	64
Not thinned	—	8	687	2-6/16	54

*On three trees, data for the crop of 1935 was lost due to an error in harvesting

On the hypothesis that biennial bearing is due to an early drain on the tree caused by the many fruits developing prior to the June drop, early thinning may be expected to increase the amount of bloom for the succeeding year. Several investigators working with other varieties in other sections have found it to do so. The results given in Table III indicate that the McIntosh responded well. While there is considerable variation from tree to tree, on the average about 25 per cent of the

spurs on the trees thinned earliest in the season produced blossoms in 1936. Given an average set, this is sufficient for a good commercial crop. The trees thinned July 15, or about 6 weeks after bloom, had blossoms on approximately 12 per cent of the spurs. The data has been studied by Fisher's method of analysis of variance which gives odds of about 19 to 1 that the improvement in blossoming on the trees thinned July 15 is statistically significant.

TABLE III—EFFECT OF THINNING MCINTOSH TO 1 FRUIT TO 50 SPUR LEAVES ON FRUIT BUD FORMATION AND YIELD OF THE SUCCEEDING SEASON

Date of Thinning 1935	Days After Bloom	Per Cent of Spurs Blossoming 1936	Average Yield per Tree (Pounds) 1936	Average Yield per Tree for 1935 and 1936 (Pounds)
June 20	21	24.6	373	426
July 15	36	11.8	168	288
August 10	62	4.0	39	194
Check	—	5.7	62	375

Average production in 1936 on the trees thinned by June 20 of the previous season was between 8 to 10 bushels, a very satisfactory yield. The average yield for the 2 years is somewhat higher on these trees than on those not thinned at all. The difference is somewhat small to be statistically significant in view of other uncontrolled factors that have a bearing on the yield. However, it must be remembered that the fruit was of satisfactory quality both seasons. The fruit from the unthinned trees consisted of approximately 16 bushels of rather small and poorly colored apples in 1935 and in 1936 of 1½ bushels of oversized apples. Its commercial value for the 2 years is far below that of the fruit from the thinned trees.

Attention is called to the very low average yield obtained on trees thinned late in the season. This practice causes the greatest loss of crop in the year of thinning without any compensating increase the succeeding year. Unless the thinning can be done early, it is best left undone.

In 1936, late spring frosts caused practically complete loss of crop in many New Hampshire orchards. Mature trees in such orchards if left without special treatment will be likely to become decidedly biennial in bearing habit. It seems fairly certain that early thinning will avert this difficulty. The practice involves considerable difficulty from the farm management point of view. Early thinning is expensive, both because of the large number of fruits which must be removed and because school boy labor commonly used for this operation is not available at this time of the year. Probably one thinning will re-establish the regular bearing habit and no further treatment will be needed until some outside influence like the spring frost again upsets the balance. If that is true, thinning to break the biennial habit may be looked on as an investment rather than as an annual cost and the extra expense may be justified.

Influence of Respiration on the Daily Rate of Photosynthesis of Entire Apple Trees

By A. J. HEINICKE and N. F. CHILDERS, *Cornell University, Ithaca, N. Y.*

IN studying the rate of photosynthesis of a green plant, we determined the amount of CO_2 absorbed from the atmosphere in excess of the amount given off by the tissue as a result of respiration. Since the two processes are going on simultaneously when the green tissue is exposed to light, we speak of apparent photosynthesis if there is a net decrease in the CO_2 content of the air, or of apparent respiration if there is a net increase. Of course respiration of the green tissue as an independent metabolic activity may easily be studied if we exclude light.

It is of interest to know whether certain treatments or sets of conditions affect respiration more than they affect photosynthesis even though it may make no difference in the net accumulation of carbon compounds in the plant.

In connection with our studies of photosynthesis during the season of 1936, we determined the apparent respiration for an entire young bearing tree growing in an alfalfa sod plot in the Cornell University orchard at Ithaca, New York. The 9-year-old McIntosh tree, having a trunk circumference of 46.4 cm with a leaf surface of approximately 100 sq cm was entirely enclosed in a large glass chamber provided with inlet and outlet for controlled air movement. The difference in CO_2 content of the ingoing and outgoing air was carefully determined in accordance with the details described elsewhere (1).

RESULTS

Table I gives the average respiration per hour at different temperature levels for the entire tree during the periods from 7:30 p.m. to 4:30 a.m. for the nights from June 1st through October. It is clear from the data that, on the whole, respiration is markedly increased with the increase in temperature. The amount of respiration is likely to be much lower than is to be expected if the preceding afternoon and the early morning hours are unusually clear. Evidently there may be enough light after 7:30 p.m. and before 4:30 a.m. to partially offset respiration. This is especially true during June and July. There were many nights in which the photosynthesis between 7:30 p.m. and 4:30 a.m. actually exceeded respiration by a small amount.

TABLE I—AVERAGE RESPIRATION (GR. CO_2 PER HOUR PER TREE) 7:30 P.M. 4:30 A.M. AT DIFFERENT LEVELS OF MEAN TEMPERATURE

1936	5 Degrees C	10 Degrees C	15 Degrees C	20 Degrees C
June.....	—	2.2	3.1	—
July.....	—	0.8	1.1	3.1
August.....	—	0.6	1.8	2.5
September.....	—	0.6	1.9	4.3
October.....	0.2	0.4	0.5	—
Average.....	0.2	0.9	1.7	3.3

During the 180 nights in which these determinations were made there were, of course, many fluctuations which indicated that other factors in addition to temperature and the small amount of radiation during twilight and early dawn, are involved in the rate of respiration. Obviously the growth activity of the plant is an important factor. For example, in June when new tissue is still being formed rapidly the respiration rate is much greater than it is during the following months. The respiratory activity falls off markedly in October after practically all growth has ceased.

TABLE II—RESPIRATION OF ENTIRE TREE DURING DAYTIME IN ABSENCE OF LIGHT

Period	Mean Degrees C	Gr Co ₂ Hr	Assimilation*
Aug. 1, 1936			
9:30 a.m.—2:30 p.m. . . .	26.1	27.1	53.3
2:30 p.m.—7:30 p.m.	26.7	26.1	33.9
Sept. 30, 1936			
9:30 a.m.—7:30 p.m.	10.0	5.8	27.9

*Apparent photosynthesis GrCo₂Hr of a comparable tree during same period.

On several occasions the large glass cage was entirely covered with light-proof paper during the daytime to prevent photosynthesis. The results in Table II indicate that the amount of respiration which occurred during such times is markedly influenced by temperature. It would appear also that there is a much greater activity at a given temperature during the daytime than there is during the night. There are only four nights during August and September in which the mean temperature was about 24 degrees C, but the highest night-time respiration recorded was 10.1 grams per hour, with an average of 9.7 grams. This is less than half as much as the daytime respiration in the dark on August 1.

TABLE III—INFLUENCE OF TEMPERATURE ON RATE OF APPARENT PHOTOSYNTHESIS OF ENTIRE TREE. (PERIOD 9:30 A.M.—2:30 P.M.)

1936 Pair	Gr.Co ₂ Hour	Mg.Co ₂ Cu M	Gr Cal Cm ²	Degrees C
1a	64.2	581	347	22.8
1b	46.0	577	346	29.8
2a	74.1	542	302	26.7
2b	57.6	558	358	35.0
3a	62.4	528	220	20.6
3b	50.6	552	219	31.1

The results of our studies on apparent photosynthesis indicated that the higher rates of assimilation rarely occur at the higher temperatures. The typical figures in Table III show clearly that high mean temperatures greatly reduce photosynthetic activity. If we assume, for example, that all the difference between cases 2a and 2b is due to increased respiration, we have a reduction of over 20 per cent in photosynthesis

with an increase in temperature of about 8 degrees C. Furthermore, if the data in Table II are representative of the rate of respiration that might occur during daylight, then we would have to add about 25 grams to the 74 grams to give us the true rate of photosynthesis at 26.7 degrees and the other conditions recorded in case 2a.

In apple trees we are likely to find the most favorable conditions for accumulation of carbohydrates during the latter part of the year, when the weather is cooler, and less favorable for high respiration even though the light conditions may not be quite so favorable for photosynthesis at that time.

TABLE IV—INFLUENCE OF RESPIRATION DURING NIGHT ON RATE OF APPARENT PHOTOSYNTHESIS OF ENTIRE TREE 9:30 A.M. TO 2:30 P.M. FOLLOWING DAY

1936 Pair	Gr.Co. Hour	Respiration*	Mg Co. CuM.	Gr Cal Cm ²	Degrees C
1a	67.8	- 1.24	536	212	23.9
1b ...	52.5	-7.86	570	390	25.5
2a	68.9	-1.04	545	294	30.6
2b	59.1	-6.26	544	337	29.6
3a	61.9	-3.91	537	161	25.6
3b ..	61.6	-8.24	531	287	25.6

*Respiration in Gr.Co.Hr for entire tree 7 30 p.m. to 4:30 a.m.

The data in Table IV suggest that high rate of respiration during the preceding night may influence the apparent photosynthesis during the period from 9:30 a.m. to 2:30 p.m. on the following day. It is conceivable that a high rate of respiration may bring about conditions in the tissue which have an inhibiting influence on photosynthesis activity. Since this condition may persist for several hours, it may be referred to as a "hang over" influence.

In concluding it may be stated that the average rate per hour of apparent respiration of an entire apple tree during the night period amounts to considerably less than 10 per cent of the average hourly rate of apparent photosynthesis during the day. It is possible, however, that during daytime the rate of respiration may be great enough to depress the rate of apparent photosynthesis as much as 20 to 30 per cent at the higher temperatures. The rate of photosynthesis will also be reduced by any other factors that increase respiration (2).

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A Summary of Some Tests With Different Kinds of Commercial Nitrogenous Fertilizers Applied to Apple Trees

By R. S. MARSH, *University of Illinois, Urbana, Ill.*

IN 1926 a 26-year-old Winesap orchard on loess soil, in Calhoun county, Illinois, was chosen for certain fertilizer tests. The trees had been well pruned and sprayed, but were not making a vigorous growth. The primary purpose was to use the orchard for extension teaching and demonstration rather than for research. However, responses to the various treatments were noticeable, and, since the block was rather uniform, there was an opportunity to make analyses which would have value in the extension program. A part of the data on the nitrogen content of certain parts of the trees that had received various fertilizers were published in 1926 and 1928 (1, 2).

In 1934, after the Calhoun county demonstration had been dropped, similar tests were started in the University orchard at Urbana. Previous fertilizer tests in the University orchard had not resulted in marked responses; the nitrate content of the soil was therefore investigated. Some of these data were published in 1935 (3).

The purpose of this paper is to present unpublished data from both localities and to summarize the two phases of the work. In Table I the percentages, on a dry-weight basis, of total nitrogen in bearing spurs from the Calhoun county Winesaps are given for a 5-year period. Almost without exception there seems to have been no marked differences between the various carriers of nitrogen as measured by total nitrogen content in the spurs. Calcium cyanamid seems to have produced total nitrogen slightly higher than the other carriers in one plot in April, 1937, and again in two plots in April, 1930. It is possible that this was due to a pronounced delay in availability. On a majority of the sampling dates, spurs from calcium cyanamid plots have contained smaller amounts of total nitrogen than the other fertilizer treatments, which is not inconsistent with the above assumption.

The total yield over a 6-year period and the grade data for 4 of the 6 years are given in Fig. 1. Ammonium sulfate and nitrate of soda have produced consistently greater yields than calcium cyanamid which seems to have had very little or no effect on total yield. The heavier applications of ammonium sulfate and nitrate of soda had given a growth response that was probably unfavorable to maximum production. It is doubtful that the fertilizers had much effect on size, grade or color. Two of the after-bloom applications have given larger fruits than most of the pre-bloom treatments. Also two of the cyanamid blocks gave larger-sized apples than those fertilized with the other carriers except where 9 pounds of nitrate of soda and $4\frac{1}{2}$ pounds of ammonium sulfate were applied. This may be due to the lower yield on the cyanamid blocks; the same reasoning can account for the small proportion of larger apples on the block fertilized with 6 pounds of sodium nitrate, where one of the largest yields was obtained. When yield, grade, and size are considered, the use of ammonium sulfate of $4\frac{1}{2}$ pounds per

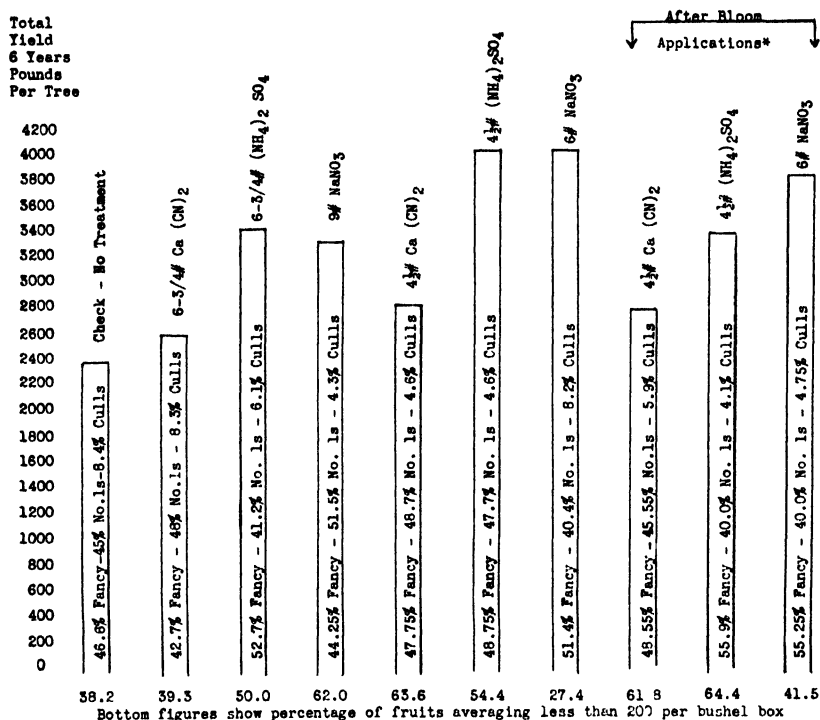


FIG. 1. Yield, grade, and size data covering a 3 to 6 year period in a mature winesap apple orchard where different carriers of nitrogen were used.

tree has given the greater economic return for the fertilizer investment. Since differences between the fertilizers in their effects on grade were questionable, and since size seems to be of less and less importance on the markets then, on the basis of yield alone, nitrate of soda would have practically the same value as ammonium sulfate. If the chart of Fig. 1 is compared with the data in Table I there seems to be little correlation.

URBANA SOIL TESTS FOR NITRATE

Further soil tests on the influence of drought on the accumulation of nitrates in the soil were made during the summer of 1936. Where there was sufficient organic matter, and where clean cultivation was practised, it was observed that nitrates would accumulate in somewhat higher amounts during a drought than in a more normal season. These data are presented in Table II.

On July 16 and August 10 soil samples from an untreated block of trees ran higher in nitrates than any from the fertilized areas. However, in this particular check block the location was such as to receive some eroded soil from adjacent areas and was in a position to maintain a higher soil moisture level than some of the other parts of the orchard.

TABLE I.—SUMMARY OF THE PERCENTAGES OF TOTAL NITROGEN ON DRY WEIGHT BASIS OF SPURS FROM WINESAP APPLE TREES

Application (Pounds)	1926		1927		1928		1929		1930	
	May 15	June 29	April 20	June 15	May 2	June 14	April 10	June 3	April 16	May 24
9 NaNO ₃	2.90	2.08	2.31	1.50	2.68	2.31	3.47	2.90	3.91	3.10
6½ (NH ₄) ₂ SO ₄	2.86	1.82	2.61	1.65	2.73	2.32	3.65	2.71	3.98	3.04
6¾ Ca(CN) ₂	2.89	1.82	2.43	1.64	2.64	2.08	3.33	2.41	4.62	2.56
6 NaNO ₃	2.98	1.89	2.81	1.73	2.64	2.05	3.58	2.23	3.76	2.90
4½ (NH ₄) ₂ SO ₄	2.61	1.80	2.67	1.46	2.87	1.99	3.53	2.57	3.75	2.89
4½ Ca(CN) ₂	2.77	1.76	3.67	1.46	2.81	1.96	3.66	2.26	3.75	2.77
*6 NaNO ₃	—	1.88	3.92	1.42	2.67	2.07	3.58	2.42	3.78	2.76
*4½ (NH ₄) ₂ SO ₄	—	2.02	2.67	1.65	2.59	2.04	3.47	2.59	3.92	2.96
*4½ Ca(CN) ₂	—	1.82	3.67	1.46	2.59	1.78	3.54	2.08	4.23	2.69
Check.	2.48	1.73	2.59	1.42	2.66	1.80	3.52	2.26	3.33	2.81

*After bloom application.

TABLE II--AMOUNT OF NITRATE NITROGEN EXPRESSED AS POUNDS PER ACRE AS DETERMINED ON SOIL SAMPLES (COLLECTED ON DIFFERENT DATES) AND TAKEN IN AN 18-YEAR-OLD APPLE ORCHARD WHICH HAD RECEIVED CALCIUM CYANAMID, NITRATE OF SODA AND AMMONIUM SULFATE

Depth of Sampling 0 to 6 $\frac{1}{2}$ inches	Dates of Soil Sample Collections 1936			
	June 19	July 16	July 28	August 10
Check	68	60	46	80
Calcium Cyanamid	48	34	32	56
Nitrate of Soda	80	52	48	64
Ammonium Sulfate	68	50	42	58

On the other hand it was sufficiently distant from the treated blocks so as not to benefit from any of the applied fertilizers. Although the data presented are incomplete, the increased amount of nitrates in 1936 over that of 1935 (3) is not as great as was expected. Also, calcium cyanamid failed to have any advantage over the other carriers of nitrogen toward increasing the soil nitrate content. This was the situation in the 1935 data where the sampling dates are comparable. However, the advantage of calcium cyanamid was indicated where the soil samples had been taken in the fall and spring of 1934 and 1935 (3).

In conclusion the data seem to indicate that calcium cyanamid fails to have any advantages over nitrate of soda or ammonium sulfate in this particular investigation. Although soil nitrates were found to be higher in the late fall and early spring where cyanamid was used, this advantage was not indicated in observation of the growth and foliage condition. The total nitrogen analyses show that over a 5-year period calcium cyanamid seems to have enough "carry over" effect to mask any difference of availability between it and the other types of fertilizers that were used in this study. Drought conditions have given increased soil nitrate nitrogen content where there was average fertility and where clean cultivation was practised.

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Effect of Cultural Treatments on the Growth and Nitrogen Content of Apple Shoots and Spurs

By J. T. SULLIVAN and CLARENCE E. BAKER, *Purdue University, LaFayette, Ind.*

CHEMICAL studies conducted on Grimes trees in an orchard soil management experiment during the early period of growth (2) have been continued with certain modifications.

The trees used in these studies are growing under three systems of soil management: (a) cultivation with an early fall sown cover crop of winter wheat or rye, (b) permanent blue grass sod which receives an annual spring application of ammonium sulphate at the rate of one-quarter pound per tree for each year of age, and (c) a mixed legume sod (chiefly alfalfa). The trees completed their fourteenth growing season in 1936 and have been under the present cultural systems for twelve years. Each treatment is duplicated in the north and in the south half of the 15 acre orchard. The original planting distance was 20 by 20 feet, but one-half of the trees were removed during the winter of 1935. Previous to 1934 the legume plots had been cultivated once a year in attempts to establish the alfalfa sod. The cultivated and the legume plots receive no inorganic fertilizer.

Previous to bearing the trees under cultivation grew more rapidly than trees in blue grass sod as measured by the yearly average trunk circumference increase and reached their maximum growth rate in 1930. The trees in sod had the lowest growth rate up to 1930, reached their maximum in 1931 and declined at a less rapid rate. (See Fig. 1.) The trees in sod now have a slightly larger average trunk girth than those in cultivation. The trees in legume sod have at all times been intermediate to the cultivated and blue grass sod plots in size and rate of growth. One of the cultivated plots (E), in spite of the annual winter cover crop is in a badly eroded condition, although the slope is very slight. Trees in this area are exceedingly weak and non-productive and show much evidence of nitrogen starvation. Comparable trees on a similar plot (B), while showing indications of low nitrogen are not suffering quite so greatly.

Trees on the cultivated plots bore their first fair sized crop in 1931 while the trees in both sod and legume plots bore their first crop in 1932. During 1931, 1932 and 1933 the amount of fruit produced by the cultivated plots was much greater than on the sod plots. With the first commercial crop on all plots in 1935 and again in 1936 the blue grass plots not only bore much more fruit than the cultivated plots but this fruit was larger and of much greater commercial value than fruit from the cultivated plots. Fruits from the legume plots were intermediate in size and amount during this period. In 1934 there was almost a complete crop failure on all plots.

Up to and through 1930, the period at which the trees were making the most rapid growth and before coming into bearing, the trees showed chemical differences (2). The trees in cultivation which were making the most rapid growth contained the most nitrogen and the least starch

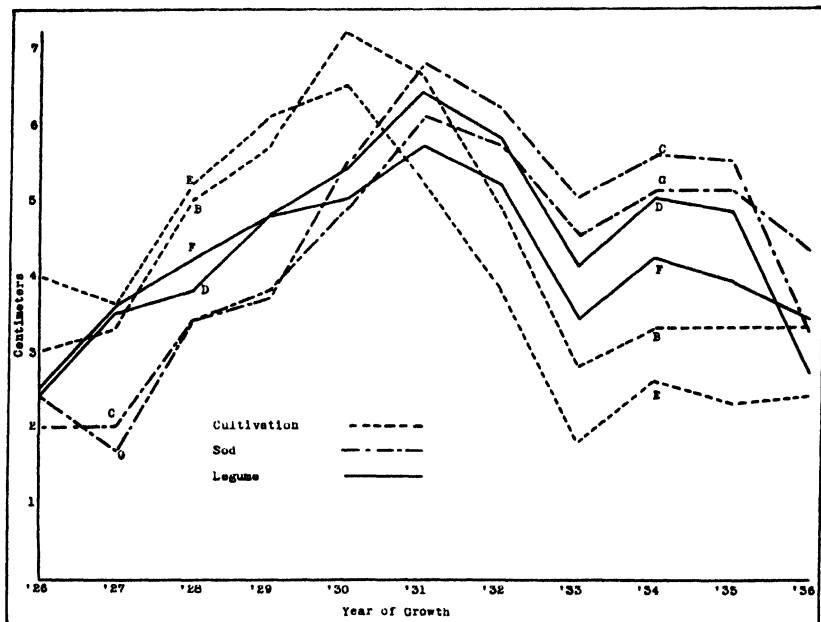


FIG 1. The average annual trunk circumference increase in centimeters of six plots of Grimes apple trees under three systems of soil management, cultivation with cover crop, blue grass sod and legume sod.

in their terminal shoots. The trees in sod, in spite of the fact that they were the only ones receiving nitrogenous fertilizer, contained the least nitrogen, the greatest amount of starch and were making the least growth. The legume plots were intermediate in all characteristics. Because of this fact the data are discussed primarily as they concern the comparison of trees grown in blue grass sod with nitrogen and under cultivation without nitrogen.

The cultivated plots came into bearing in 1931. Analyses of terminal shoots in June of that year showed that the nitrogen content of the trees in sod had made a considerable relative increase and was almost equal to that of the cultivated trees. (See Table I.) No analyses were made in 1932 but in 1933 the upward trend of the nitrogen content of the sod trees was very noticeable. In the current season's growth from terminals and from spurs (Table II) the nitrogen content was highest in the sod plots. At this time also the average dry weights of the shoots collected were determined. The dry weight produced per terminal during 1933 was highest in the sod (April 4, May 20) but the dry weight produced from spurs (both bearing and non-bearing) was highest in the cultivated plots (May 1). At a later date (May 24) less consistent differences were seen in the spurs. It is to be noted that at that time the cultivated trees were bearing fruit but making a lower trunk circumference increase and the sod trees were making the largest trunk increase but producing less fruit than the cultivated trees.

TABLE I.—THE NITROGEN CONTENT AND THE AVERAGE WEIGHT OF DRY MATTER PRODUCED IN TERMINAL SHOOTS

Year Sampled		1931		1933		1934		1935		1936					
Date Sampled		Apr. 21	June 2	Apr. 4	May 20	Jan. 3	Apr. 12	Jan. 29	May 9	Apr. 9	June 16				
Year Produced on Tree		1930	1930	1931	1932	1932	1933	1933	1934	1935	1936				
<i>Nitrogen in Percentage of Dry Weight</i>															
B Cultivation.....	.644	.440	1.17	.771	.504	1.77	.561	.699	.700	.734	.944	.775	3.10	.982	1.50
E Cultivation.....	.568	.405	1.01	.746	.488	1.64	.561	.686	.675	.722	.881	.630	2.59	.919	1.34
C Sod.....	.539	.445	1.14	.683	.493	1.91	.587	.753	.735	.811	1.050	.890	3.50	.848	1.59
G Sod.....	.493	.467	1.09	.739	.547	1.81	.676	.808	.773	.814	1.022	.909	3.48	.869	1.51
D Legume.....	.621	.447	1.00	.715	.479	1.83	.621	.826	.826	.818	1.034	.780	3.22	.925	1.58
F Legume.....	.580	.427	.93	.723	.491	1.79	.622	.782	.758	.775	.925	.751	3.14	.884	1.51
<i>Grams of Dry Matter per Shoot</i>															
B Cultivation.....	3.46	2.59	.286	3.98	1.71	1.51	2.04	.52	.53	.221	.69	1.83			
E Cultivation.....	2.26	2.03	.253	3.12	1.11	1.26	1.61	.37	.30	.208	.29	1.21			
C Sod.....	4.67	3.84	.306	4.93	2.32	2.41	4.24	1.29	1.03	.388	1.64	1.97			
G Sod.....	3.02	2.42	.285	4.44	1.91	2.06	3.42	1.35	.98	.329	1.44	1.95			
D Legume.....	5.07	3.40	.241	5.23	2.68	2.58	3.70	1.31	1.19	.288	1.36	1.98			
F Legume.....	4.35	3.15	.275	5.97	2.76	2.62	4.03	.79	.81	.273	1.15	2.11			

TABLE II—THE NITROGEN CONTENT AND THE AVERAGE WEIGHT OF THE DRY MATTER PRODUCED FROM SPURS

Year Sampled	1933				1934		1935		1936	
	May 1		May 24		May 2		May 24		May 15	
Type of Spurs	Bearing	Non-Bearing	Bearing	Non-Bearing	Bearing	Non-Bearing	Bearing	Non-Bearing	Bearing	Non-Bearing
<i>Nitrogen in Percentage of Dry Weight</i>										
B Cultivation	3.96	4.30	2.49	2.39	4.26	2.12	2.49	2.21	2.16	1.62
E Cultivation	3.66	4.15	2.24	2.02	4.04	1.78	2.02	1.92	1.82	1.42
C Sod . . .	4.48	4.87	2.75	2.72	4.48	2.57	3.11	2.91	2.42	1.75
G Sod	4.31	4.73	2.73	2.65	4.45	2.47	3.13	2.90	2.26	1.76
D Legume	4.00	4.40	2.56	2.37	4.52	2.57	2.74	2.57	2.34	1.76
F Legume	3.97	4.33	2.68	2.50	4.37	2.36	2.52	2.36	2.27	1.72
<i>Grams of Dry Matter per Spur</i>										
B Cultivation	.253	.099	.690	.426	.077	.523	.451	.382	.423	.549
E Cultivation	.223	.090	.631	.364	.065	.523	.421	.423	.397	.498
C Sod . . .	.206	.086	.765	.400	.118	.578	.598	.501	.334	.538
G Sod	.212	.080	.660	.358	.079	.604	.488	.489	.363	.529
D Legume	.234	.097	.788	.372	.095	.614	.488	.540	.369	.530
F Legume . . .	.246	.094	.707	.400	.096	.668	.439	.476	.390	.574

The same tendency was found in 1934. Terminal shoots were sampled twice before growth began and non-bearing spurs twice at a later date. In all cases the cultivated trees produced the least dry matter and contained the lowest percentage of nitrogen.

In 1935 the sod and legume plots came into bearing. By this time sod trees had a slightly larger trunk girth and the annual increase was decidedly in their favor. The trees in sod also have produced more and larger fruit than the trees in cultivation in 1935 and 1936. Samples of mid-terminal leaves taken at three periods of growth during each of the 1934 and 1935 seasons (1) show that the cultivated trees had the smallest leaves on both the fresh and dry weight basis and that these leaves were consistently lowest in total nitrogen as compared with leaves from trees in the other treatments. The leaves from the trees in blue grass sod were highest in weight and nitrogen and those from the legume plots were intermediate. Micrometer measurements of permanent mounts showed the leaves from the sod plots to be 16.1 per cent thicker and those from legume plots to be 9.5 per cent thicker than those from cultivated plots.

Terminal shoots were sampled in January and on May 9 of 1935. Bearing and non-bearing spurs were sampled on May 24. In both old and new terminal growth and in all spur growths more dry matter of a higher nitrogen content was produced in the sod plots.

The year 1936 followed the first year in which all plots bore a heavy crop of fruit. Terminals were sampled on April 9 and on June 16. The dry weight produced on both occasions was greatest in the sod but the sod plots were lower in nitrogen on the first date but not after growth began. The non-bearing spurs were sampled on May 15 and June 16. On the first of these dates the dry weight was lowest in the sod, the reverse of the situation in the terminals but like the terminals the non-bearing spurs from the trees in sod had the highest nitrogen. At the later date the dry weight differences were not noticeable.

The sod plots which were highest in nitrogen in 1935 produced more dry matter in the terminals in 1936 while the cultivated plots, low in nitrogen in 1935, produced more spur growth in 1936. As only non-bearing spurs were sampled the low average dry weight of the sod plot spurs may have been caused by the greater number of bearing spurs on the sod plots. Observation indicated that the sod plots had blossomed more heavily than the other plots in 1936. However, for both years (1933 and 1936) in which the cultivated plots produced more dry matter in the non-bearing spurs, this superiority disappeared at a later date.

Summing up the history of this young orchard to date, terminal and trunk growth of Grimes apple trees have been correlated with the nitrogen content of the trees. Up to the time of bearing trees in cultivation and cover crop without inorganic nitrogen made the greatest growth and contained more nitrogen than trees in blue grass sod receiving a nitrogenous fertilizer. The blue grass sod plots which received an annual application of ammonium sulphate but in which the trees competed for the nitrogen with the grass, made slower growth during this same period and came into bearing later, but eventually surpassed the

cultivated plots in growth, yield, and nitrogen content. The amount of spur growth was not always correlated with the amount of the terminal growth. In 1933 and in 1936 the cultivated plots, low in nitrogen and always producing less terminal growth, produced at times a higher dry weight of spur growth. The legume plots, because of the difficulty of establishing the sod, resembled the cultivated plots in the early part of this period and the sod plots in the later part. As a result they have been intermediate to the other two treatments in all characteristics.

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Individual Tree Yield Records in a Commercial Apple Orchard

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IN view of the time and expense elements involved in a commercial apple planting, the tree assumes importance as an individual unit of production. With this in mind, a record of individual tree production was begun in 1930 on about 150 acres of bearing apple trees in the Simpson orchards. The methods of recording suggested by Hodgson (1) were used with necessary modifications. In 1931, records were extended to 200 acres. These records were continued for 4 years on the entire acreage, and for 7 years on about 100 acres.

The purpose of making such records was to make a precise analysis of the various blocks as to individual tree performance and need and by correcting these needs to increase production. It was hoped that 4 years would be sufficient for drawing definite conclusions, and for showing clearly those areas and individual trees which were consistently unproductive. According to Sax and Gowen (2) the existence of *inherent* differences in productiveness has not been definitely established in case of clonal varieties of the apple. Production, however, may be effected by variable rootstocks.

Scoring was done as shortly before harvest as possible, as earlier scoring was found to be inaccurate. Numbers from one to five were used to indicate relative productiveness. This method was adopted as most nearly equalizing variations due to differences in size or age of trees and, to some extent, varietal variations.

For recording, waterproof parchment tags were used similar in design to those described by Hodgson (1). However, these proved unsatisfactory as too many were accidentally lost by pruning and removal. Also the printing weathered rapidly. Many tags were indistinguishable after 1 or 2 years. Where waterproof varnish or shellac was applied, the results were even less satisfactory. The protective covering soon cracked off and in so doing completely removed all printing with the varnish.

After the first year the scores were merely recorded on cross section paper, with special designations for trees not yet in full bearing; weak or dying trees, odd varieties and topworked trees, and so forth. These charts were completed as varieties ripened, and were filed together at the end of the season. For the purposes of analysis, the scores of each tree for the 6-year period were placed in appropriate tree squares. The highest scoring trees were marked with blue pencil and the lowest with red. This record was of value in marking filler trees for removal. In some cases, permanent trees were removed and fillers left as permanents, due to this past performance record coupled with field observation as to size, vigor, tree injury and disease. In one case the fillers and permanents of two entire rows were reversed, in the interest of increased production.

The block of trees charted in Fig. 1 was of especial interest as it has been one of the least productive blocks of a 120-acre planting.

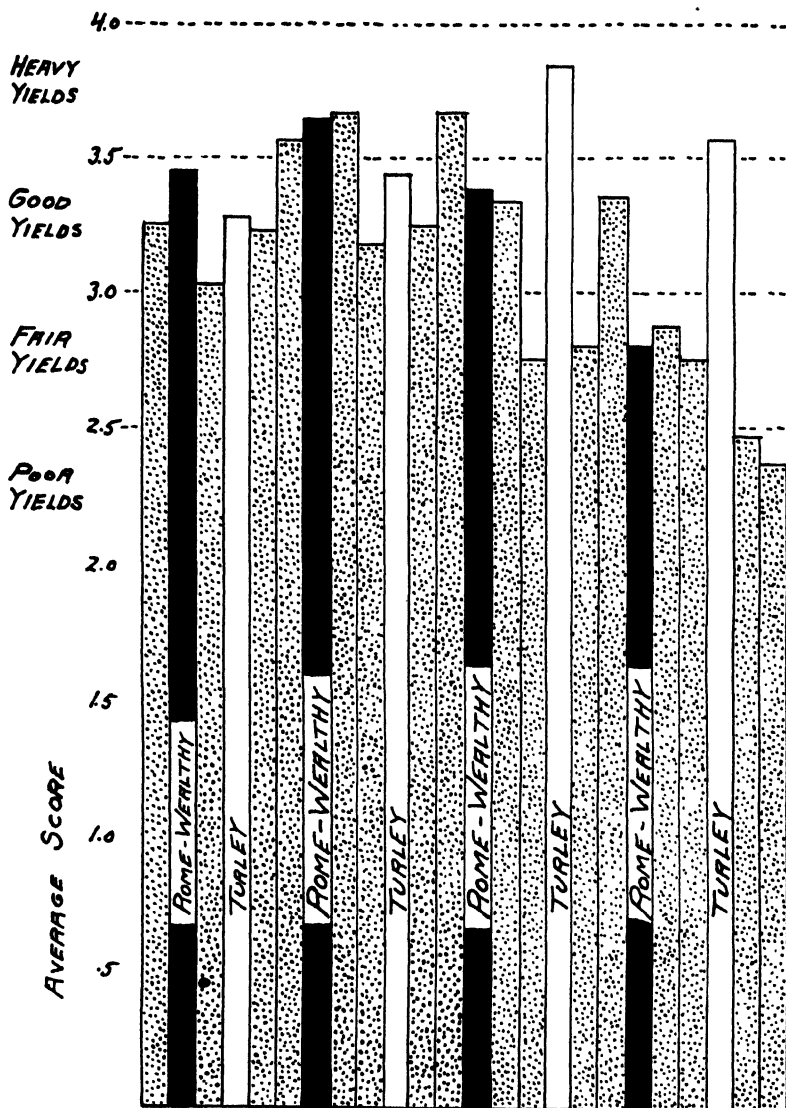


FIG. 1. Pollination study from six years' individual tree yield records. (Stippled area = Winesap).

This block was set to Winesap since it was the most promising site of the entire orchard. Unfortunately there were no pollenizers of bearing age on three sides of this area. The nearest sources of pollen were Rome and Transparent, at least 100 yards from the west edge of the field. This fact probably explains why the yield of the outer rows

to the west is higher than the outer rows to the east. As the trees normally bloom sufficiently for at least fair crops, suspicion soon pointed to pollination. Two years after the records were begun a series of three or four favorable seasons resulted in apparently satisfactory sets of fruit, although final yields were reduced by heat and drouth. During these years the correlation between yield and distance from pollinizer rows was not as clearly apparent to the eye as was later found from record analyses.

Charting of these yield records was undertaken in an attempt to learn just what correlations existed relative to pollination. The results as shown in Fig. 1 and Table I give a surprisingly clear and definite picture of the situation.

TABLE I- YIELD SCORE OF TREES SHOWN IN FIGURE 1. ROW NUMBERS CORRESPOND TO THOSE OF THE GRAPH

Row Number	Number of Trees Recorded	6 Years' Totals of Scores	Average Score for 6 Years	Row Number	Number of Trees Recorded	6 Years' Totals of Scores	Average Score for 6 Years
1	4	78	3.25	13	16	324	3.38
2	7	145	3.45	14	19	380	3.33
3	6	109	3.03	15	16	264	2.75
4	8	154	3.28	16	16	369	3.84
5	8	155	3.23	17	18	302	2.80
6	7	150	3.57	18	20	400	3.33
7	8	175	3.65	19	17	284	2.80
8	8	176	3.67	20	22	379	2.88
9	11	209	3.17	21	21	346	2.75
10	10	206	3.43	22	23	493	3.57
11	14	272	3.24	23	16	237	2.47
12	10	221	3.68	24	19	270	2.37

The rows of Turley and Rome-Wealthy had been planted as pollinizers. At that time little was known of Turley as a pollen variety. Its apparent Rome ancestry lead to the supposition that it would produce viable pollen. (Although a Winesap seedling, Turley fruit sometimes exhibits marked similarity to Rome Beauty.) Turley has since been found worthless as a pollen variety.

DISCUSSION

In the chart (Fig. 1) all replants, trees fanned by pruning and filler trees, and those for which complete data are lacking have been eliminated. As the rows vary in length from 4 to 23 recorded trees, computations are on the per tree basis.

The yields for 1936 are not included as the season was so unusual and all yields low. Bouquets used in 1936 on rows normally the lowest in production raised their yield to the highest of the block.

The Rome-Wealthy rows have been more productive than here indicated. Only the Rome trees were scored the entire 6 years. In addition, half the Rome trees were topworked to Gallia and have not bloomed or set as heavily as have the regular Rome. This has lowered the average yield for these rows materially. The actual difference in

yield between Winesap and Turley was greater than here indicated, as shown by actual picking records. In other words, a good or a full Turley tree may be expected to yield more actual picked bushels, than a good or a full tree of Winesap, of about the same size. The only accurate data for Fig. 1 was the tree record score, with no means of showing the full inter-varietal yield differences. However the purpose of Fig. 1 is primarily to show actual pollination effects, and merely to suggest varietal comparisons.

DISCUSSION

The conclusions drawn from the work in this orchard have been checked with field observations. Six years of careful checking would seem to establish rather definitely the following conclusions, at least under Indiana conditions.

Effective Distance of Pollination:—The charted analysis of 6 years' individual records shows clearly the effect of distance from pollen row on adjoining Winesap rows. During normal or unfavorable pollinizing conditions the distance of effective pollination seems very limited. In every case the second Winesap row from its pollinizer suffered a decided reduction in yield. Similar results have been reported by Tukey for the sweet cherry (3). The effect of nearby plantings of Rome, Transparent and Grimes definitely affected a limited area along the nearer sides of this block.

Where large bouquets were placed between trees in a row, a marked increase in yield extended only to the nearer half of adjoining trees, with some effect on the entire tree. The placing of 40 or 50 such bouquets in the east section of this block, supplemented by 20 hives of bees, produced only slight increases in yield, as far as could be observed or shown.

From these data it is clearly evident that the outside or at least the second row of a block should be set to a pollinizer.

Five rows between pollinizers is too much. Perhaps sufficient pollination may occur during very favorable seasons. However, it is during the unfavorable season that the value of sufficient pollen becomes evident. These are the years when the commercial returns are normally the greatest, and the proper inter-planting of varieties may be the determining factor between success and failure.

Bouquets:—The only bouquets found practical were those where large limbs 6 to 15 feet in length were cut from filler trees and placed in 50-gallon barrels. Bees do not work freely where the blossoms are wilted or are crowded together. Large limbs often remain fresh as long as 2 weeks, sometimes actually setting fruit.

Varietal Need of Pollination:—The most striking point brought out by the 6 years' records was the difference in pollen required for a satisfactory set on Winesap and on Turley. No counts were made as to actual numbers of fruits set. From a commercial point of view it was sufficient that Turley produced per tree more than twice as many bushels as the Winesap in the same block during the most favorable Winesap years. Perhaps the difference in yield may partially be accounted for by the difference in average size of the two varieties. Two

Ben Davis trees in Winesap rows have consistently outyielded surrounding Winesap, although both had equal opportunities for pollination.

It should be borne in mind that the original intent of the tree records was for comparative purposes within the varieties. Thus these records do not show a varietal difference in yield as great as the actual difference.

Practical Value of Individual Tree Records:—In conclusion, it may be added that the practice of keeping careful records develops a keener eye and a closer touch with the individual needs of a given planting. There comes the fuller realization that an orchard is a group of individuals, each with its individual needs. Such records furnish an opportunity for checking all trees that need special treatment, removal, or replacement. They furnish a practical orchard map which will be referred to numerous times and for many purposes.

In contrast to citrus yield records, 4 years' records on apples do not seem sufficient for removing trees, especially before they have reached full bearing. Some young apples have had a record of 3 consecutive off years followed by 3 years of good to heavy production. Older trees sometimes exhibit a similar performance. However, many low scoring trees located by records of individual production may be removed at the end of 4 years where the cause of unproductiveness is apparent and any remedy unpracticable.

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Some Further Observations on the Depletion of Subsoil Moisture by Apple Trees¹

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ONE year ago there was presented to this society evidence that apple trees, growing on the deep, porous loess soils of eastern Nebraska, deplete the subsoil moisture to great depths (1). The rate and extent of the usage of this water depends not only upon annual rainfall, but also upon age and spacing of the trees and probably also upon variety and soil management. Undoubtedly this depletion is a progressive affair, exhaustion occurring first near and directly below the tree and proceeding outward and downward as the tree grows older. Complete exhaustion throughout the root zone unquestionably is the final result unless precipitation or supplemental water supplies a part or all of the orchard's water needs. In the latter case there will be no drain upon subsoil reserve and in the former only such as may be needed to make up any deficiency.

The investigational methods and procedure have been the same as previously reported (1) except that in some cases sampling has extended deeper, *i.e.*, more than 30 feet. Also hygroscopic coefficients have been determined for many samples. New areas have been examined and results found to verify the earlier conclusions. They also indicate that with suitable soil conditions the withdrawal of subsoil moisture may occur from depths of 40 feet or more. Much resampling has been done in areas examined earlier, the second sample being taken as near as possible to the same spot sampled last year. Most of this latter work has been done at the University Fruit Farm at Union, Nebraska and at a nearby orchard.

Conditions during the period intervening between the sampling dates have been very severe on plant life. Unusually high temperatures throughout the summer and the exceedingly high ones in July undoubtedly greatly increased the evaporation rate and therefore demand for water on the part of the plant. Table I shows the total precipitation at the University Fruit Farm during each month of the past 3 years. Snowfall is calculated at 10 per cent water. In all 3 years, rainfall has been below the long time average (31.30 inches at Nebraska City, 62-year average) for that section of Nebraska and two have been severe drouth years. The 1936 water shortage was slightly more severe than that for 1934 although the rainfall was somewhat better distributed, more of it coming during the summer season. In each of these seasons (1934 and 1936) 25 per cent or more of the rainfall came as light showers which added little or nothing to the soil moisture available for the tree. Furthermore, where a green vegetative ground cover was present even a larger share became unavailable for tree growth.

In assembling data, averages have been made for 5 foot zones in order to simplify presentation. Relatively little significance, however, can be attached to figures for the 1- to 5-foot levels insofar as subsoil mois-

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TABLE I—MONTHLY TOTAL PRECIPITATION* AT THE UNIVERSITY FRUIT FARM, UNION, NEBRASKA, 1934, 1935 AND 1936

Month	1934 (Inches)	1935 (Inches)	1936 (Inches)
January	2.77	.00	2.50
February	.99	.45	.50
March	.97	.81	.35
April	.00	.80	2.73
May	.35	6.90	2.33
June	3.43	2.85	1.25
July	.53	2.79	1.25
August	.57	.81	1.47
September	4.30	5.38	5.76
October	1.88	4.74	.70
November	3.28	1.25	.20
December	.75	.00	—
Total for the year . . .	19.82	26.78	19.04

*Snow depth is calculated as 10 per cent water.

ture is concerned. This zone acts as a sponge, absorbing rainfall only to give it up immediately as the tree requires. In a few instances there are indications of some temporary replenishment in the second zone but these may be disregarded.

In Table II will be found data secured from samples taken under 18-year old Delicious trees growing on the University Fruit Farm. These are the averages of four holes made at locations where there is little loss of surface water by runoff. Since the sampling stations were located near the tree trunk evaporation losses would be at a minimum, because of shade, and also very little water would be used by competing shallow rooted plants. Table III shows comparable data secured from stations located 22.3 feet from the trees (planting distance 30 x 33 feet). Here there was a soil cover of various types of annual and perennial crops which during this particular season made much less growth than usual.

TABLE II—EXTENT OF SUBSOIL MOISTURE REMOVAL BETWEEN JULY 31, 1935 AND AUGUST 19, 1936 AT VARIOUS DEPTHS UNDER DELICIOUS APPLE TREES

Depth (Feet)	Moisture Percentage			Hygroscopic Coefficient	Proportion of Available Water Already Used (Per Cent)
	1935	1936	Loss		
1-5	16.3	13.6	2.7	10.9	84
6-10	14.9	13.3	1.6	11.3	88
11-15	13.9	13.2	.7	10.6	84
16-20	17.5	13.8	3.7	9.5	63
21-25	20.0	15.6	4.4	8.4	43
26-30	18.3	16.5	1.8	9.3	49
Average	16.8	14.3	2.5	10.0	71

Total loss (as per cent of 1 foot) 75.0 (30 x 2.5)

Equivalent in inches 11.56

Total rainfall between sampling dates 23.39

Total water loss in inches 34.95

TABLE III—EXTENT OF SUBSOIL MOISTURE REMOVAL BETWEEN JULY 31, 1935 AND AUGUST 19, 1936 AT VARIOUS DEPTHS IN INTERSECTIONS OF DELICIOUS APPLE TREES

Depth (Feet)	Soil Moisture Percentages			Hygroscopic Coefficient	Proportion of Available Water Already Used (Per Cent)
	1935	1936	Loss		
1-5 ..	16.0	13.4	2.6	10.9	86
6-10	16.6	15.5	1.1	11.3	75
11-15	19.2	16.5	2.7	10.6	56
16-20	20.8	18.0	2.8	9.5	41
21-25	21.6	20.1	1.5	8.4	23
26-30	19.6	20.0	+ .4	9.3	24
Average	19.0	17.3	1.7	10.0	51

Total loss (as per cent of 1 foot) 51.0 (30 x 1.7)

Total loss equivalent in inches 7.85

Total rainfall between sampling dates 23.39

Total water loss in inches 31.24

In these data it will be noted that moisture depletion of the subsoil has continued, the loss being greatest directly under the tree. Not a great deal of water disappeared from the second 5-foot zone at either location or from the third one underneath the tree. Conceivably this may be because the moisture content there was nearing the point of unavailability for this species. Heavy losses occurred between 16 and 25 feet but only slight ones lower.

The average soil moisture loss at the tree station was 2.5 per cent per foot and 1.7 per cent at the intersection. Converting these percentages to inches by multiplying by 30 (30 foot depth) and dividing by 6.5 (6.5 per cent water in 1 foot equals 1 inch) the total water loss from the soil was 11.56 inches at the tree and 7.85 inches at the intersection. When these amounts are added to the rainfall, 23.39 inches, coming between the sampling dates, the total water lost by direct evaporation, usage by competing plants and to supply the needs of the tree was 34.95 and 31.24 inches at the respective points. Thus, an average of 9 to 10 inches of water above the amount coming by precipitation was required for the orchard needs.

Assuming that the hygroscopic coefficient represents 40 per cent of the total water holding capacity of the soil, then 1.5 times the hygroscopic coefficient becomes the maximum amount of available water which can be held. Taking the difference between these amounts and the hygroscopic coefficient as the amount of moisture which has already been extracted from the soil and figuring the ratio between these amounts, the figures in the last column of Tables II and III are secured. It would appear, therefore, that between 51 and 71 per cent of the available soil water has already disappeared — and this planting is only 18 years old. Comparing the present amount of available moisture with that found a year earlier it will be seen that a reduction of over 25 per cent has taken place — in other words a continuation of the present drain on soil moisture for 3 years will completely exhaust the soil of available moisture in the upper 30 feet. Moisture for additional use must then come from greater depths if they can be reached by the roots.

The above time estimate may be even too generous since there is some question as to the ability of the apple tree roots to extract all soil moisture above the hygroscopic coefficient point. In no case tested to date has over 85 to 90 per cent of calculated available water been removed.

Samples taken in the nearby Banning orchard show a similar change of moisture content but the loss since last year has not been so great. In this case clean cultivation eliminated competing plant growth and hence there was no loss through this avenue. In the Hoppert and Howard orchard in the extreme southeastern corner of the state there was practically no change since a year ago. Here, however, precipitation was appreciably greater and furthermore the orchard was located on an eastern slope well protected from the hot drying summer winds.

CONCLUSIONS

Sampling additional orchard locations to depths of 40 feet or more has verified previous conclusions that orchards use subsoil water from great depths. Resampling locations at the University Fruit Farm after an interim of approximately 1 year indicates that the amount of depletion was greatest directly under the tree. The greatest change also occurred below the 16-foot level. Between 31 and 35 inches of water was used by the trees, competing plants and direct evaporation. Since rainfall was less than 24 inches, the average amount taken from the soil was 9 to 10 inches. Such a loss continued through three more years would remove all available water to a depth of 30 feet. There is some indication that apple trees can remove only about 90 per cent of calculated available water (hygroscopic coefficient $\times 1.5$) from soils of the loess type.

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Root Distribution of a Baldwin Apple Tree in a Heavy Soil

By DAMON BOYNTON and E. F. SAVAGE, *Cornell University, Ithaca, N. Y.*

STUDIES of moisture and air in soil of the Cornell University orchard made it desirable to have more accurate knowledge about the effect of depth and distance from the trunk on the quantity of absorbing apple tree roots in a unit volume of soil. Rogers and Vyvyan (1), Oskamp (2), and Aldrich, Work and Lewis (3), have made the most complete quantitative investigations of this sort. Oskamp and Batjer (4) have demonstrated the important influence of soil type on the rooting of apple trees, but since their excavations were at a uniform distance from the trunk, the effect of distance from the trunk was not considered.

In the summer of 1936 a vigorous 25 year old Baldwin apple tree in the Cornell University orchard was cut down. It was in the center of a square of four McIntosh trees which were 40 feet apart, so that the trunk of the Baldwin was 28 feet from each McIntosh trunk. A ditch was dug across the Baldwin trunk and 13 feet on each side of it along one diagonal of the square. The completed excavation was 2 feet wide and 4 feet deep except for the central 12 feet which was 5 feet deep. The soil was removed in sections 6 inches or 1 foot deep and 1 foot long; the roots were screened out, sorted, dried at 105 degrees C and weighed 1 gram.¹

The soil is mapped as Dunkirk silty clay loam. The profile at the position of the tree is briefly described as follows: depth 0 to 6 inches, medium brown silty clay loam; 6 to 9 inches, yellow brown heavy silty clay, mottled rusty and grey, transitional to the layer below; 9 to 24 inches, dull red-brown clay with columnar cracks, calcareous at 20 inches; 24 to 60 inches, olive grey silt with thin seams of plastic clay, lacking columnar structure, calcareous, laminated.

The description shows that the texture of the soil is heavy throughout the profile. The presence of calcareous material at 20 inches, together with ground water records and yield records of adjoining McIntosh trees indicate that the profile at this position is not well enough drained to produce the best apple yields over a period of years. The orchard is in sod.

Concentration of roots is expressed as grams per cubic foot of soil in Table I. Part A presents the data for roots smaller than 2 mm diameter. This includes the smallest separable roots, and it is assumed that they represent the active absorbing root area. The data are arranged so that the weights found southwest of the trunk, can be compared with those found in comparable locations northeast of the trunk. It is evident that there is a wide range of root concentration at any one depth and distance from the trunk. But the weights per cubic foot in

¹Roots larger than 10 mm diameter were not brought to constant weight.

each trench and the average weights show unmistakably that the density of small roots decreases both with distance from the trunk and with depth. Forty-six per cent of the small roots were in the top foot, 21 per cent were from 1 to 2 feet, 17 per cent from 2 to 3 feet, 11 per cent from 3 to 4 feet, and 5 per cent from 4 to 5 feet. The concentrations of small fibrous roots were much the greatest in the top 3 feet within 8 feet of the trunk. Part A of Table I also indicates that small fibrous roots were present at a greater depth within 6 feet of the trunk than farther out.

Relative densities of roots in the size group 2 to 10 mm, to be found in part B of Table I, were strikingly similar to the densities in the smallest group. As would be expected, roots 10 mm and larger, shown in Part C, were heaviest per unit volume of soil close to the trunk, and practically all roots larger than 10 mm were in the top 3 feet within 8 feet of the trunk.

The data presented in Table I lead to the conclusion that the root system of this tree extended in the surface foot somewhat more than 13 feet out from the trunk, and extended not much more than 8 feet from the trunk at a depth of 5 feet. The greatest density of absorbing roots was in the top 3 feet within 8 feet of the trunk. These results agree in general with the finding of Aldrich, Work, and Lewis (3), Beckenbaugh and Gourley (5), Oskamp (2), Furr and Magness (6), Rogers and Vyvyan (1) and others.

As Marth (7) has pointed out, the greater density of fibrous roots close to the trunk does not mean that there are actually more total fibrous roots close to the trunk. The distribution of fibrous roots in the total area occupied at each 2 foot interval of distance from the trunk is presented in Table II on the assumption that the average densities in Table I are truly representative. It is evident that there is about the same weight of fibrous roots in the soil 6 to 12 feet from the trunk, as in the soil within 6 feet of the trunk, although the density decreases directly with distance from the trunk.

TABLE II—CALCULATED WEIGHTS OF ROOTS LESS THAN 2 MM DIAMETER IN THE AREA OCCUPIED AT EACH 2 FOOT INTERVAL OF DISTANCE FROM THE TRUNK (GRAMS)

Depth (Inches)	Distance from Trunk (Feet)					
	0-2	2-4	4-6	6-8	8-10	10-12
0-12	161	833	791	915	814	608
12-24	147	279	320	246	226	276
24-36	111	268	188	176	305	221
36-48	73	109	226	167	136	111
0-48	492	1489	1525	1504	1481	1216
Per cent of total . . .	6.4	19.3	19.8	19.5	19.2	15.8

This study was carried out under the direction of Dr. A. J. Heinicke.

TABLE I.—ROOT DENSITIES OF A 25-YEAR-OLD BALDWIN APPLE TREE IN HEAVY SOIL IN GRAMS PER CUBIC FOOT OF SOIL, AND PER CENT OF TOTAL ROOTS IN SEVERAL SIZE GROUPS

Depth (Inches)	Trench Direction from Trunk	Distance From Trunk (Feet)							Per Cent of Total
		A. Roots Less Than 2 mm Diameter							
		0-2	2-4	4-6	6-8	8-10	10-12	12-13	
0-6	N. E.	9.0	30.2	18.8	13.4	7.6	2.4	2.4	25.0
	S. W.	16.4	20.2	15.6	11.2	3.5	3.2	3.0	
	Average	12.7	25.2	17.2	12.3	6.5	2.8	2.7	
6-12	N. E.	11.6	27.2	9.2	11.4	10.2	7.2	5.4	21.0
	S. W.	14.2	10.6	6.6	5.4	5.6	4.8	3.0	
	Average	12.9	18.9	7.9	8.4	7.9	6.0	4.2	
0-12	N. E.	10.3	28.7	14.0	12.4	8.9	4.8	3.9	46.0
	S. W.	15.3	15.4	11.1	8.3	5.5	4.0	3.0	
	Average	12.8	22.1	12.6	10.4	7.2	4.4	3.5	
12-24	N. E.	12.3	8.1	5.8	3.4	2.5	2.8	2.4	21.0
	S. W.	11.1	6.6	4.3	2.2	1.4	1.2	2.1	
	Average	11.7	7.4	5.1	2.8	2.0	2.0	2.3	
24-36	N. E.	9.1	9.5	3.5	2.5	4.0	2.0	1.8	16.7
	S. W.	8.4	4.6	2.5	1.5	1.3	1.1	0.8	
	Average	8.8	7.1	3.0	2.0	2.7	1.6	1.3	
36-48	N. E.	5.5	4.9	3.2	2.1	1.6	0.9	0.4	11.7
	S. W.	6.0	4.8	4.0	1.6	0.7	0.7	0.4	
	Average	5.8	4.9	3.6	1.9	1.2	0.8	0.4	
48-60	N. E.	1.7	1.9	1.2	—	—	—	—	46.1000
	S. W.	2.7	3.1	4.2	—	—	—	—	
	Average	2.2	2.5	2.7	—	—	—	—	

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Soil Moisture and Fruit Growth in an Orchard Situated on Shallow Soil in the Hudson Valley, N. Y., 1936

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IN Dutchess and Columbia Counties of New York State, two of the soils that support considerable acreages of fruit trees are called Dutchess gravelly loam and Cossayuna gravelly loam. They are moderately fertile, rather well drained soils of glacial till origin and they commonly include areas of shallow phase. Presence of bed rock very close to the surface obviously makes a soil unfit for orchard purposes, and a depth of 4 feet or more of soil accompanied by satisfactory drainage conditions is clearly favorable for fruit trees. But the minimum depth of soil necessary for best production of apples under the rainfall and evaporation conditions of the Hudson Valley has been a matter for conjecture. The work described here was done in order to get more specific information on this subject.

THE EXPERIMENT

A soil moisture study was undertaken in a 12-year-old McIntosh orchard situated on soil mapped as Cossayuna gravelly loam. Two adjacent plots of six trees each were located; plot I on soil 24 inches deep; plot II on soil 42 inches to more than 4 feet deep. The average trunk circumference of the trees in plot I was 71 cm and in plot II it was 97 cm, so that the trees on shallow soil were uniformly smaller than the trees on deep soil. However, all were growing vigorously and the previous year's terminal growth was about the same in both plots. Planting distance was 30 by 30 feet, but since the trees were young they were not yet crowded. Six pounds of Cyanamid per tree had been spread in the fall of 1935 and a light application of manure was made during the growing season of 1936. The crop on all trees was moderate.

Four composite soil samples of each foot depth were taken in both plots every 2 weeks during the summer. Each composite was made up of three borings, two at a distance of 8 feet and one 15 feet from the trunks. Thus each point in Fig. 1 represents 12 sampling locations and four samples. The per cent of soil moisture was figured on the basis of oven dry soil after gravel was removed. Moisture equivalent was determined by centrifuging, and permanent wilting per cent by growing sunflowers in cans of the soil. Average permanent wilting percentages determined in this way were all lower than wilting points calculated from moisture equivalent.

At the same time soil moisture samples were taken, the circumferences of 15 tagged fruits on five trees in each plot were recorded. The fruits were on the outsides of the trees, convenient for measurement, and were selected at random.

Accumulated rainfall for 2 weeks previous to each sampling date was determined in a standard raingauge, and "accumulated evapora-

tion" for the same period was determined by use of a Livingston white bulb atmometer. The data are to be found in Fig. 1.

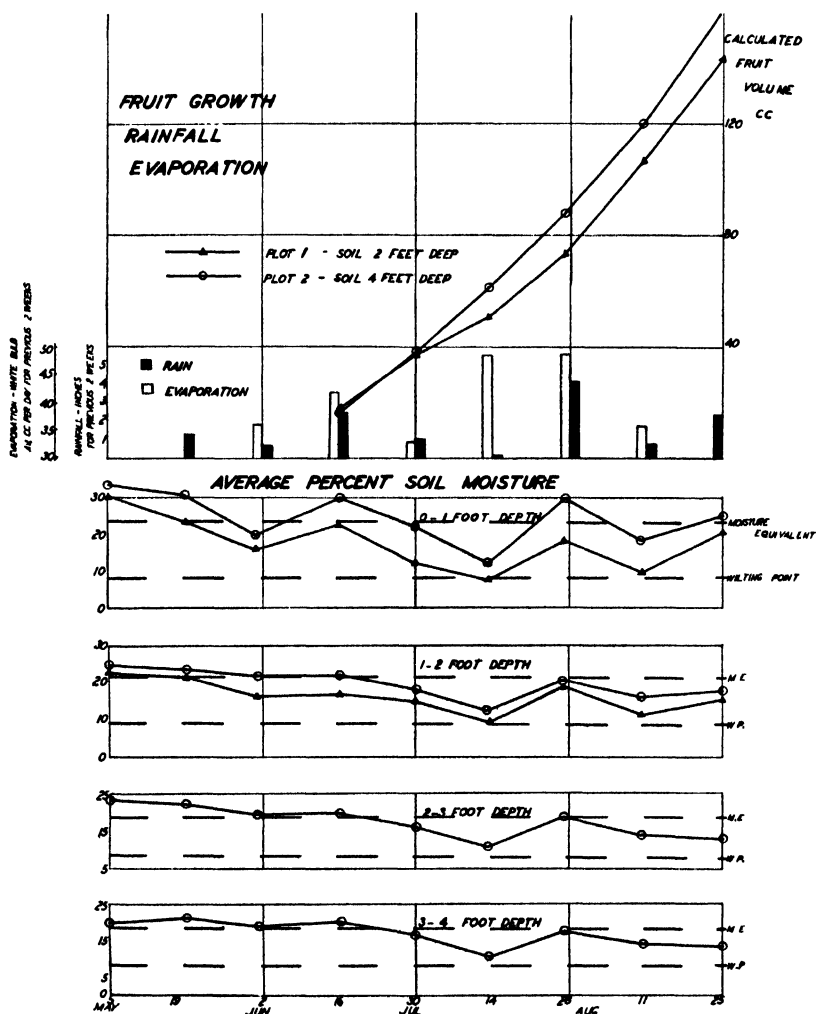


FIG. 1. Soil moisture and fruit growth in an orchard situated on shallow soil in the Hudson Valley, New York, 1936.

RESULTS

A consideration of the results of this soil moisture study must give due weight to the errors of sampling. The samples taken at any one date were about one-thousandth of one per cent of the soil volume occupied by roots of the experimental trees. Average per cent moisture of four composite samples in each plot at every date are assumed to indicate

the trend of soil moisture. Since only four samples are used in computation of each average, probable errors determined for these averages are not mathematically sound. However, the maximum deviation from any average was generally less than 2 per cent of dry weight. The deviation was least in soil close to wilting point and greater as the amount of available water increased. It should be mentioned that there was a deviation from the mean in one case as great as 8 per cent. Some such wide variations are inevitable as the work of Taylor and Furr (1), and Work and Lewis (2) has demonstrated.

The rainfall found in the gauge for the whole period May 5 to August 25, 1936, was 13.80 inches, as compared with an average of 14.78 inches for the 4 months period from May 1 to August 31 at the nearest weather station (Albany). The 1 inch "deficiency" came in May, when rainfall was 2.11 inches as compared with the Albany average of 3.33 inches for May. June and August rainfalls were about average, and July rainfall was more than a half inch above average. In spite of the fact that July precipitation was above average, there was a period from June 30 to July 13 when only 0.2 inch of rain fell. This was preceded by a period of 2 weeks when 1.1 inch of rain fell and was followed in the July 13 to July 27 period by precipitation of 4.3 inches. Evaporation from the white bulb atmometer was highest during July; it was practically the same for the June 30 to July 13 period when rainfall was lowest as it was for the July 13 to July 27 period when rainfall was highest.

Fruit circumference measurements were made on June 15 and every 2 weeks after that. Average fruit volumes were calculated from the circumferences of 75 fruits on trees growing in soil 20 to 24 inches deep (Plot I) and from an equal number on trees growing in soil 42 inches deep or deeper (Plot II). Fig. 1 shows that the average volumes on both plots were practically the same on June 15 and June 30. But on July 13 fruit volume for plot I was less than for plot II and during the remainder of the season this difference in size was maintained. That is, on August 25, the fruits on the shallow phase plot were 6 days behind the fruits on the deep soil plot in size, and this difference was established during the period of June 30 to July 13 when rainfall was only 0.2 inch.

Average per cent soil moisture in both plots was above moisture equivalent on May 5 (Fig. 1) and remained well above the permanent wilting point of sunflowers at all depths in both plots until the first 2 weeks of July. On July 13 soil moisture in the surface foot and in the second foot of plot I was about at the wilting point. While there was a marked drop in average soil moisture of plot II at this date, permanent wilting point was not reached by any layer. Fruit growth rate dropped in plot I during the previous 2 weeks period, and did not slow down in plot II. The sharp decline in available soil moisture and fruit growth on plot I accompanied a 2 weeks period of very little rain and high evaporation. On July 27, the next sampling date, an abundant supply of soil moisture in both plots at all depths was again present, having been restored by accumulated precipitation of more than 4 inches. Fruit growth in both plots proceeded at the normal rate and

soil moisture did not decline to wilting point in any layer during the rest of the experiment.

This study is presented here as evidence that during a year of normal precipitation in the Hudson Valley, lack of rainfall for 2 weeks may cause reduction of fruit growth on trees situated on soil only 2 feet deep. In this experiment the decline in fruit growth accompanied a drop of average per cent soil moisture from about 35 per cent of available capacity to wilting percentage in a period of 13 days. The apparent relationship between reduction in fruit growth and approach of wilting point is in agreement with results of Hendrickson and Veihmeyer (3), Lewis, Work, and Aldrich (4), Taylor and Furr (1), Furr and Magness (5), and others. The effect of the shallow soil on the ability of trees to withstand rather short periods of drought supports the results of Magness, Degman and Furr (6). The fact that all this soil came close to wilting point before reduction in fruit growth occurred indicates a rather complete permeation with absorbing roots.

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Soft Scald of Jonathan Apples in Relation to Respiration

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IT has been found by various investigators (1, 2, 6, 7, 8, 9, 10, 11) that certain physiological disorders of apples such as soggy breakdown, soft scald and low-temperature breakdown are increased by holding the fruit at temperatures of 50 to 70 degrees F for various periods previous to storage at 30 to 32 degrees. The severity of these disorders generally increased to a maximum and subsequently decreased with the length of time the fruit was held at the higher temperatures. Harding (5) reported that the rate of respiration of Grimes Golden apples likewise increased to a maximum and subsequently decreased with the length of time the fruit was held at the higher temperatures (50 and 60 degrees) and he also reported that soggy breakdown developed when the fruit was transferred to 30 or 32 degrees during the period of high respiratory activity; otherwise, no breakdown developed.

Likewise Harley and Fisher (6) found that the $O_2:CO_2$ ratio in the internal atmosphere of Jonathan apples decreased with delay at 70 degrees F to a minimum that corresponded to a maximum development of soft scald in the apples transferred to 32 degrees. They considered the minimum $O_2:CO_2$ ratio indicated the maximum respiratory rate and suggest a possible predisposition of the tissue to low temperature injury induced by an abrupt checking of respiration when the respiratory activity is relatively high.

Kidd and West (7, 8) observed a similar relationship in Bramley Seedling apples and concluded that the fleshy tissues of the apple break down sooner when the fruit is placed in cold storage at the respiratory peak or climacteric than they do before or after this stage. They suggest, however, (8) that there was some factor other than the pitch of respiratory activity concerned in the causation of low-temperature breakdown since early gathered fruit had a higher respiratory activity but took longer to develop breakdown than late gathered fruit.

In 1935 some studies were made of soft scald of Jonathan apples (grown near Frederick, Maryland) in which the fruit was held at 70 degrees F for various lengths of time previous to storage at 32 degrees. The daily rate of respiration was determined at 70 degrees by means of the respiration apparatus previously described (4). Smoothed curves of the rates of respiration at 70 degrees of the different lots of apples are shown in Fig. 1. The numbers on the curves indicate the amount of soft scald that developed at 32 degrees when the fruit was transferred from 70 to 32 degrees at the times indicated by the numbers. As indicated in Fig. 1, pickings were made at five different maturities (shown by Roman numerals) and in the third picking small apples ($2\frac{1}{4}$ to $2\frac{1}{2}$ inches in diameter) and apples lacking in red color were also stored. The condition of the fruit at harvest is indicated in Table I. In the second and fourth pickings soft scald was determined

the time of transfer and the development of soft scald in Jonathan such as has been reported for soft scald of Jonathan (6), for soggy breakdown of Grimes Golden (5) and low-temperature breakdown of Bramley Seedling (7, 8). Thus in the case of pick I (Fig. 1) the fruit developed no soft scald when transferred after 3 days at 70 degrees at which time it was respiring at nearly its maximum rate (28.5 mg CO₂ per kg hr.) but developed 74 per cent of soft scald when transferred after 9 days at 70 degrees, at which time the respiratory rate had decreased to about 25 mg per kg hour and 51 per cent soft scald developed when the respiratory rate had decreased to nearly 23 mg per kg hour. Similar relations existed with the other lots in which transfers were made at intervals. With these lots the maximum rate of respiration was approached by the third day yet very little or no soft scald occurred in any of the lots transferred at this time. In picks III, "III small" and IV the respiratory rate was about the same after 6 days as after 3 days but the percentage of soft scald was very much greater. After 9 days at 70 degrees the respiratory rates of these lots were distinctly lower than after 3 or 6 days yet the percentage of soft scald to develop was still very high. It is of interest to note that pick V that had the highest respiratory rate had generally the lowest percentages of soft scald. These results are in accord with those of Gerhardt and Ezell (3) who found no consistent relation between respiratory activity at the time of storage and the development of soft scald on Jonathan. These results, however, are distinctly opposed to the hypothesis advanced by Harding (5) that the respiratory activity of apples at the time of storage serves as an index to the storage capacity of the fruit, particularly with respect to soggy breakdown (soft scald has been classified (11) as one type of soggy breakdown). These results might be interpreted to indicate instead that soft scald is a disorder distinct from soggy breakdown or that Jonathan apples respond differently than Grimes Golden apples in this respect. That Harding's hypothesis is not entirely applicable even to Grimes Golden was indicated by his data since Plagge (9) reported high percentages (60 per cent or more) of soggy breakdown with transfers made after 2 to 5 weeks at 50 degrees. With apples from the same lots Harding (5) reported relatively high respiratory activity (16.8 to 18.1 mg CO₂ per kg hr.) after 2 to 4 weeks at 50 degrees but not after 5 weeks when the respiratory rate had dropped to 13.3 mg which was less than during the first week at 50 degrees when less than 4 per cent of soggy breakdown developed. Thus contrary to his hypothesis a high percentage of soggy breakdown was associated with a relatively low respiratory intensity in the transfer made after 5 weeks at 50 degrees. Likewise in the 1929-30 season no soggy breakdown occurred with immediate storage lots but did after 3 weeks delay in Grimes Golden apples from both nitrated and non-nitrated plots, yet the respiratory intensity was less in the apples from both plots after 3 weeks at 50 degrees than in the initial determinations after 3 days at 50 degrees. Likewise Kidd and West (7) show over 60 per cent low-temperature breakdown after 4 weeks' delay and only about 12 and 5 per cent breakdown after 6 and 7 weeks' delay although the fruit was still respiring as rapidly after 6 and 7 weeks as after 4 weeks.

It is of interest to note that the shape of the curves of respiration varied considerably. Harding (5) states that his curves were very similar for both years and consisted of four stages which he described as (I) a period of accelerated ascent, (II) a short period of rapid descent, (III) a longer period of gradual descent, and (IV) a senescent period in which the respiratory rate increased. The curves shown in Fig. 1 generally correspond to those described by Harding for the second and third stages only. The fruit apparently was not held long enough for the fourth stage to be apparent. A first stage of rapid but not "accelerated" ascent is shown by curves I, II and V and correspond with Harding's (5) curves for the 1928-29 season. The other curves in Fig. 1 (except III undercolor) generally show a slight gradual ascent during the first stage and correspond to Harding's curves for the 1929-30 season in which little or no increase was apparent and in which his "period of accelerated ascent" is shown diagrammatically as a horizontal line.

CONCLUSIONS

Holding Jonathan apples at 70 degrees previous to storage at 32 degrees influenced the amount of soft scald which generally increased to a maximum with 6 to 9 days' delay at 70 degrees and subsequently decreased. The respiratory rate of Jonathan apples at 70 degrees generally increased for a period and subsequently decreased. The extent and rapidity of the increase varied considerably with the different lots. There was no apparent relation between the respiratory rate and the maturity of the fruit or between the respiratory rate at 70 degrees F at the time of transfer and the amount of soft scald that developed at 32 degrees.

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Some Suggestions on the Preparation of Diseased Plant Materials for Photographing¹

By H. H. FLAGGE and T. J. MANEY, *Iowa State College, Ames, Iowa*

FOR the purpose of making a permanent record of certain types of diseases of apples which are considered somewhat difficult to photograph, several valuable aids have been employed by the writers in the pomological laboratory at Ames. Although the technics described herein for the preparation of materials for photographing are simple, it is considered that the information may be of some value to others working with similar horticultural products.

In photographing Jonathan spot, good results are not consistently obtained because the dark spots tend to be masked out in highly colored specimens by anthocyanin pigments. Lack of detail in such photographs is particularly apparent for the mottled type of Jonathan spot, *i.e.*, the type in which the spots are confluent and in which the discolored areas blend into the natural coloring of the apple.

The writers recognize the value of color filters and panchromatic films in the photographing of highly colored plant materials. However, a method which largely disposes of the more intense colors in the material has been found to be simple and to give more definite results. The method is based upon the bleaching property of sulphurous acid, and for apples is essentially as given below.

Affected apples are placed under a bell jar or in a large wide-mouth bottle with a small dish of burning sulfur. It is more convenient to have the fruit and sulfur in place and then drop a short, heated piece of glass tubing on the sulfur just before closing the container. The sulfur will burn sufficiently to produce a high concentration of sulfur dioxide, which combines with the moisture of the fruit to produce sulfurous acid. After several hours the sulfurous acid bleaches most all the red color from the fruit.

After bleaching, red apples will appear to be yellow with a light pink cast on the more deeply colored side. Jonathan spots, which normally appeared blackish, turn to a light red color and stand out prominently against the lighter background. Even the smallest Jonathan spots are readily visible after treatment and are easily photographed. Bleached apples become soft and rubbery and take on a cooked appearance, but stand up well and are conveniently handled and photographed. The flesh of apples becomes lighter in color and the seeds bleach from a dark to a light reddish-brown, as the gas readily penetrates throughout the fruit. In some instances more than one exposure to the gas is desirable, or the fruit may be left exposed to the gas over night.

The writers have used the method to bleach the color from apples, cranberries, grapes, radishes, beets, red cabbage and flowers. The method appears to be satisfactory for those materials containing anthocyanins. The color of tomatoes, peppers, yellow flowers, and yellow and green apples is not eliminated by the treatment. The method is of value for photographing the diseases sooty-blotch and fly-speck (*Leptothyrium pomi*), apple scab (*Venturia inaequalis*), apple blotch (*Phyllosticta solitaria*), bitter pit and soggy breakdown, and for such

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defects as spray and frost injury, limb rub and lenticel checking, particularly when these occur on highly colored fruit. A comparison of photographing Jonathan spot before and after bleaching the fruit is shown in Fig. 1. The result of photographing an apple before bleaching, using a panchromatic film and a color filter, is shown, as well as that of photographing the same apple after bleaching, using a color blind

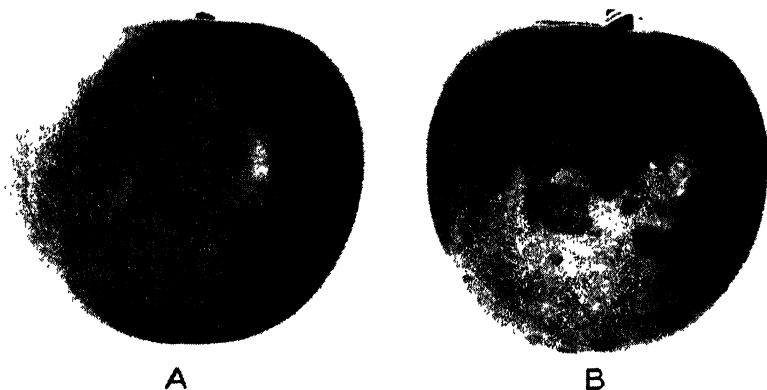


FIG. 1. A. Jonathan spot on Jonathan apple, photographed before bleaching; with the use of a panchromatic film and red color filter. B. The same apple as in "A", photographed after bleaching out red color; with the use of a color blind film and without color filter.

film without a color filter. The comparison clearly indicates the advantages of the bleaching method to facilitate photographing when color masks out defects.

Another photographing aid used in this laboratory is that of retarding the oxidation of freshly cut fruit surfaces by the application of juices from citrus or pineapple fruits. The oxidation of sections of apples cut to show internal characteristics of bitter pit, drouth spot, mealy breakdown and similar diseases has been retarded as much as an hour or more by covering the cut surfaces with lemon juice, whereas untreated surfaces have become badly discolored in a few minutes. The method affords a convenient way to photograph the natural contrast in color between sound and discolored tissues noticeable immediately after sectioning the fruit, and is particularly advantageous when large numbers of cut specimens are to be photographed, or when many photographs are made in rapid succession.

A specific and convenient method of photographing apple scald is given mainly because of the difficulty usually experienced in photographing this disease. It is simply that of taking advantage of the fact that apples which become scalded with oiled paper treatment show the disease in much sharper detail and contrast than those which scald without oiled paper. Although the use of oiled paper largely prevents or retards the development of apple scald, usually some apples develop the disease with the oiled paper treatment, and these may be selected for photographic specimens to good advantage.

Bitter Pit of Gravenstein Apples

I. The Effect of Environmental Temperature During the Growing Period

By ROBERT M. SMOCK, *University of California, Davis, Calif.*

INTRODUCTION

BITTER pit constitutes one of the major sources of wastage of the Gravenstein apple in California. This paper is first in a series related to certain orchard and storage factors affecting bitter pit. Previous work in California done with the Gravenstein by Allen (1) has indicated the influence of storage temperature and fruit maturity on this trouble.

Smith (12) has supplied an excellent review of the problem of bitter pit and in conclusion points out the paucity of information which might indicate its nature. Barker (4) has prepared an annotated bibliography of some 215 references on the subject and he too points out the need of further work along certain lines.

SUGGESTED CAUSES OF BITTER PIT

Barker's annotated bibliography indicates the numerous theories that have been advanced as to the cause of bitter pit. One of the most widely quoted modern theories is that of Carne, Pittman, and Elliot (6). Their thesis is that bitter pit is a necrosis of immature starch filled cells of rapidly growing apples. This necrosis results from excessive transpiration followed by osmotic action between starch filled cells and cells filled with sugar. As a consequence of this osmosis, the affected cells are desiccated and finally die. These investigators base their theory on the observation that starch may be found in bitter pitted areas whereas surrounding areas are starch free. Smith (1) has pointed out that persistence of starch in pitted areas cannot be regarded as cogent evidence of the theory.

Other current theories with regard to the cause of bitter pit are the virus theory offered by Atanasoff (2), local asphyxiation as described by Kidd and West (8), and the theory of boron deficiency as suggested by Atkinson (3). The last mentioned theory has particular reference to a cork disease found in New Zealand and it is only suggested by Atkinson that boron deficiency may be the cause of bitter pit as it is found in the United States.

Boron deficiency:—To test the possibility of boron deficiency as being causative of bitter pit, a 10 year old Gravenstein tree was injected with boric acid. On May 14 and 15, 1936 two roots on opposite sides of the tree were injected with 2 liters each of .1 per cent boric acid. Leaves on several limbs above the roots injected showed injury by May 22 but the injury was not cumulative or severe. At harvest time fruits were picked from the injured limbs and were stored for 10 days at 32 degrees F and then 10 days more at 75 degrees. Fruit from these limbs showed as much as 22 per cent bitter pit. This amount was equal to or more than that exhibited by adjoining trees. McClarty (11) of

British Columbia has performed a more extensive test which indicated that while boric acid would correct drought spot and "corky core" it would not influence the production of bitter pit. Brooks (5) has confirmed the opinion that bitter pit is a trouble unrelated to boron deficiency.

Effect of Environmental Temperature on Bitter Pit:—A critical examination of the effect of environmental temperature during the

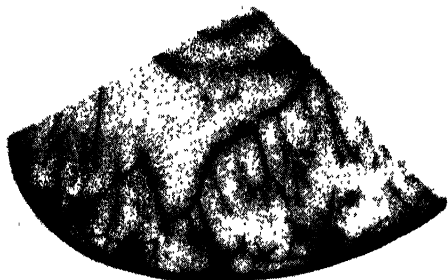


FIG. 1. Bitter pit in the Gravenstein. Transverse section 4 mm in the thickness cleared in xylol to show the location of vascular bundles and the pits. The pits are the dark areas under the skin. Pits usually but not always associated with bundles.

growth of the fruit on bitter pit has not been made. Wallace (14) has noted that potted Bramley Seedlings growing at high temperatures and low humidities in a soil with a high water content developed 100 per cent bitter pit in storage. Masee (10) considered bitter pit due to too high an atmospheric temperature during the early period of ripening. Kaiser (7) believed that bitter pit was due to damp, sunless weather.

Kidd and West (8) have placed considerable emphasis in temperature fluctuations during the growing period. They stated that apples subjected to extremes of temperature during a 24 hour period while actively growing might develop internal atmospheres which, while harmless at higher temperatures, might cause local brown heart or bitter pit in badly aerated spots in the flesh while the lower night temperatures were in effect.

METHODS

A 14 year old Gravenstein tree which had a case history of comparatively little bitter pit over a period of several years was used. The tree was in full bloom on April first and set a fairly heavy crop of fruit. Fruits were thinned to 6 inches on May 6. A normal irrigation was given the tree on June 26.

Four large limbs facing from southeast to southwest were selected. One large limb was enclosed in a Celo-glass chamber and heated during the night hours. This limb is designated in the discussion as Environment I. The sides of the chamber were removed during the day. Electricity was not conveniently at hand so a wickless kerosene camp stove was used as a source of heat. To avoid fumes in the chamber, the heater was enclosed immediately below the chamber and a flue ran from the heater into the chamber. A T-shaped pipe was placed at the floor of the chamber and thus the flue ran the length of the chamber. Heat was

supplied entirely by radiation from the flue. An asbestos baffle over the flue prevented the hot air from rising directly from the flue and striking the fruit.

A second limb (Environment II) was enclosed in an insulated chamber with Celo-glass sides with a cooling compartment running along the top of the chamber. The Celo-glass was two thicknesses thick to provide some insulation. This insulated compartment had a baffle extending up 8 inches above the floor of the compartment on one side and on the other a baffle extended down into the chamber about 6 inches. This provided for a natural circulation of air over the ice and down into the chamber. The water from the melted ice was piped off into a large container to prevent irrigation of the tree. One hundred to 150 pounds was used daily in this compartment. It was cut into 25 pound pieces and distributed in the ice compartment.

A third limb (Environment III) was used as a control.

A fourth limb (Environment IV) was completely enclosed in a Celo-glass chamber. Heat from the sun's rays was trapped by the enclosure.

Hygro-thermographs were placed in Environments I, II, and III to record humidity and temperature. The instrument which recorded data for the normal environment (III) was placed in an official meteorological instrument shelter a few feet from the tree. All instruments were protected from direct light.

Growth measurements of 30 fruits were taken at weekly intervals in each treatment except Environment IV. The largest diameters were measured with calipers.

Fruit was considered ready for picking when it had reached a size of at least $2\frac{1}{4}$ inches, and a ground color of $1\frac{1}{2}$ -2.¹ This necessitated as many as three pickings in most cases. After being harvested, all fruits were graded for color and all having more than a color of "2" were discarded. The fruit was placed in 32 degrees F storage for 10 days, then was removed to a ripening room with a temperature of 75 degrees and relative humidity of 80 to 90 per cent. They were inspected for bitter pit upon removal from storage and after 10 days of ripening at 75 degrees F.

TEMPERATURE AND HUMIDITY RESULTS

Table I indicates the temperatures and humidities which prevailed in three experimental environments. Several criticisms might be levelled at the method of raising and lowering temperatures. In Environment I air circulation was possible only through convection currents. This fault was not as serious as might be expected, however. The greatest temperature difference noted from one part of the chamber to another was 6 degree F. In Environment II not only the temperature was influenced by the ice cooling, but also the humidity and light. Of necessity, the Celo-glass sides were in place during the day. This reduced the light intensity somewhat and maintained a higher humidity than normal. It is thought, however, that conditions in Environment II at least partially simulated conditions which might be

¹Color determined by color chart of the California Department of Agriculture.

TABLE I—HEAT UNITS, TEMPERATURES AND RELATIVE HUMIDITIES IN ENVIRONMENTS I, II, AND III, 1936

Date	Heat Units Above 50 Degrees F			Mean Temperatures (Degrees F)			Mean Relative Humidities		
	Day	Night	Total	Day	Night	24 Hour Period	Day	Night	24 Hour Period
<i>Environment I (Lamb Enclosed, Heated at Night)</i>									
May 6-May 13	200	135	335	83	73	78	—	—	—
May 13-May 20	184	127	311	81	71	71	43*	63*	54*
May 20-May 27	215	133	348	86	72	74	40	53	46
May 27-June 3	172	100	272	79	68	73	—	—	—
June 3-June 10	184	159	343	81	76	78.6	28*	42*	35*
June 10-June 17	240	181	421	90	80	85	38	46	42
June 17-June 23	245	138	383	89	72	80.5	27	40	33
June 24-June 30	235	149	384	88	73	80.5	27	43	35
Mean.	209	140	349	84.6	73.1	77.5	33.8	47.8	41.0
<i>Environment II (Limb Enclosed, Cooled with Ice)</i>									
May 11-May 13	27	10	34	66	55	60	—	—	—
May 13-May 20	53	10	63	60	52	56	72*	75*	73*
May 20-May 27	108	24	132	68	54	61	62	67	64
May 27-June 3	57	0	57	60	45	52	—	—	—
June 3-June 10	54	0	54	60	48	54	58*	65*	61*
June 10-June 17	125	59	184	72	60	66	52	63	57
June 17-June 23	96	51	147	70	58	64	55	63	59
June 23-June 30	108	7	115	67	50	58	43	48	45
Mean.	78	20	98	65.3	52.8	58.7	57.0	63.5	60.0
<i>Environment III (Normal Outside)</i>									
May 6-May 13	200	53	253	83	59	71	—	—	—
May 13-May 20	176	44	220	79	57	68	48*	72*	60*
May 20-May 27	220	76	296	86	63	74	46	71	58
May 27-June 3	151	17	168	75	53	64	—	—	—
June 3-June 10	146	43	189	74	57	65	35*	62*	49*
June 10-June 17	202	85	287	84	64	74	42	88	65
June 17-June 23	245	94	339	89	64	76	40	61	50
June 23-June 30	235	69	304	88	60	74	39	59	49
Mean	197	60	257	82.2	59.6	70.9	41.5	68.8	55.3

*Not a complete week's data

found in a humid climate where temperatures are lower, humidities higher and light intensity less than that experienced in central California.

Tufts (13) has expressed differences in temperature in "heat units". A heat unit is described as 1 degree Fahrenheit per day (*i.e.* lasting for 1 day) above a given base temperature. Lilleland (9) has indicated that apricot fruit growth can be correlated with heat unit summations with a base line of 50 degrees F more closely than with a base line of 35 or 42 degrees F. A base line of 50 degrees was chosen in computing heat unit summations for this study.

Table I indicates that, during the night hours, more than twice as many heat units were supplied to fruits in Environment I as to control

fruits in Environment III. Not quite enough heat was supplied, however, to completely eliminate night and day fluctuations. For the 8-week period there was an average difference of 14 degrees F in the mean temperatures for the night hours between Environments I and III. Temperatures in Environment II were consistently cooler both night and day than normal outside temperatures.

Table I also indicates that the relative humidity during the day in Environment II was about 16 per cent more than in the normal Environment (III) over the 8 week period. The relative humidity during the day in Environment II was about 23 per cent greater than in Environment I. The hygrothermograph recording "normal" temperatures and humidities was in a shelter and humidities there ran slightly higher than in Environment I during the day. During the night hours the relative humidity in Environment I was slightly less than normal due to the higher temperatures prevalent there.

As has been stated continuous records were not taken of the temperature and humidity in Environment IV. Frequent readings of a thermometer inserted into the chamber indicated that temperatures in the chamber ran 15 to 20 degrees higher than outdoor temperatures taken in the sun with a thermometer. Diurnal fluctuations in the chamber were as great as 60 to 65 degrees F.

The temperature and humidity results may be summarized as follows to show what relative climates were maintained in the four environments:

Environment I	Relatively little diurnal temperature fluctuations
Environment II	A cool, humid climate
Environment III	A "normal" climate with wide diurnal fluctuations in temperature; prevailing day temperatures high.
Environment IV	Very great diurnal fluctuations with very high day temperatures.

GROWTH RECORDS

Fruit growth records taken during the 8 week period appear in Fig. 2. By the end of the second week of treatment apples in Environment I were significantly larger than those in II or III. It was not until the end of the sixth week, however, that the apples in III were larger than those in II. In no case are the differences between treatments as great as those reported by Lilleland (9) in his study with the apricot. There are two possible explanations for this lack of any *great* influence on growth. One explanation is that treatments were started on May 6 when the fruits were already $1\frac{1}{4}$ inches in diameter. Had the treatments started earlier when the fruits were smaller and the nights cooler, the effects of heating might have been more marked. Another explanation might be that apples have a lower heat unit requirement than apricots and there was almost enough heat in even Environment II to supply its requirements.

The effects of the various treatments on fruit maturity was equally if not more marked than on fruit growth. On the average, fruit in

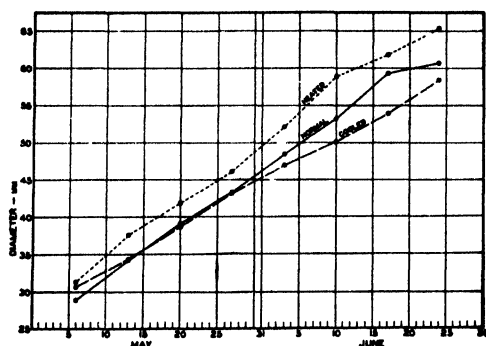


FIG. 2. Fruit growth of Gravenstein apples as affected by three different environments. Cross diameter measurements made of 30 fruits.

Environment II was ready for harvest about 8 days later than that in Environment I.

EFFECT OF ENVIRONMENTAL TEMPERATURES ON BITTER-PIT

Table II indicates that the effect of environmental temperature on the development of bitter-pit was apparently negligible. No significance is attached to the fact that a small amount of slight bitter-pit developed as a

result of several treatments. The differences are considered small because 13 per cent of slight bitter pit is considered to be a small amount of bitter-pit. Trees particularly subject to bitter-pit often develop 75 to 90 per cent of a severe type of the trouble. Certainly no treatment accentuated the amount over the normal (III) and it is highly questionable if any treatment reduced the amount normally experienced on the tree.

TABLE II—PERCENTAGE OF BITTER PIT IN APPLES GROWN IN THREE ENVIRONMENTS

Picking Date	Environ- ment	Pressure (Pounds)	Size (Inches)	Color Ratings	Bitter Pit After 10 Days Storage at 32 Degrees F	Bitter Pit After 10 Days at 75 Degrees F Follow- ing Storage at 32 Degrees		
						Slight	Severe	Total
First Picking								
June 26	I	19.2	2½	2	0	0	0	0
July 1	II	18.3	2½	2	0	0	0	0
June 26	III	18.8	2¾	2	0	13.7	0	13.7
July 1	IV	—	2½	2½	0	0	0	0
Second Picking								
July 1	I	18.9	2½	2	0	0	0	0
July 4	II	18.2	2½	1½-2	0	13	0	13
July 1	III	18.2	2½-2¾	2	5	6	1	7
Third Picking								
July 4	I	19.5	2½	1½-2	0	0	0	0
July 8	II	17.5	2½	2	0	0	0	0
July 4	III	18.5	2½	1½-2	0	0	0	0

The bitter-pit which developed in the apples from Environment II (cooled) was all of an internal type. The fruits had to be cut to show the pitted areas which occurred rather deep in cortical tissue.

It is concluded that even environmental temperature during the

growing period may affect the amount of bitter-pit it is not as important as certain metabolic factors in the tree. Results which will be reported in a later paper will show that a study of certain physiological conditions within the tree and certain storage practices offer much more hope of finding a solution to the problem of bitter pit. It is very possible that temperature as it affects certain of these metabolic factors may exert an indirect influence on bitter pit.

INFLUENCE OF EXPOSURE OF FRUITS ON BITTER PIT

If environmental temperature influences the development of bitter pit materially, it would seem that the exposed sides of the fruits might develop more or less than the unexposed sides. The exposed sides of apples are often 10 to 15 degrees warmer during the day than the unexposed sides.

On July 1, 1936 approximately 50 fruits were picked. Before being removed from the tree the margins of exposed sides were marked with India ink. These fruits were stored at 32 degrees F for 10 days and then at 75 degrees F for 10 days. Ten per cent of the apples developed slight bitter pit but there was no correlation whatsoever between the exposed and unexposed sides of the fruits. There were pitted areas as frequently in the exposed area as in the unexposed.

EFFECT OF ENVIRONMENTAL TEMPERATURE ON SUGAR CONTENT OF FRUITS

Fruits of the same degree of maturity were selected at each harvest for sugar analyses. Samples were also taken after the fruits had ripened for 10 days after the storage period.

Table III shows that at all three harvests there was consistently

TABLE III—SUGAR CONTENT OF GRAVENSTEIN APPLES FROM THREE ENVIRONMENTS*

Samples Taken at Harvest Time				Samples Taken After Ripening 10 Days			
Sampling Date	Environment	Reducing Sugars (Per Cent)	Total Sugars (Per Cent)	Sampling Date	Environment	Reducing Sugars (Per Cent)	Total Sugars (Per Cent)
<i>First Picking</i>				<i>First Picking</i>			
June 26	I	6.24	8.18	July 15	I	6.82	9.00
July 1	II	5.28	7.40	July 20	II	6.66	8.81
June 26	III	6.26	8.26	July 15	III	7.07	9.00
<i>Second Picking</i>				<i>Second Picking</i>			
July 1	I	5.74	7.64	July 20	I	6.76	8.52
July 4	II	5.37	7.59	July 25	II	5.97	7.64
July 1	III	6.82	8.69	July 20	III	7.70	9.48
<i>Third Picking</i>				<i>Third Picking</i>			
July 4	I	—	—	July 25	I	7.40	9.41
July 8	II	5.09	7.52	July 28	II	7.07	9.29
July 4	III	—	—	July 25	III	8.30	9.89

*Results expressed on basis of fresh weight.

†Environment I—heated at night; II—cooled; III—normal.

less reducing and total sugars in fruits from Environment II than in the other environments. Unfortunately no samples were taken for analyses from Environments I and III at the time of the third harvest but fruits from this harvest after being ripened, also reveal that there was less reducing and total sugars in fruits from the cool chamber. Differences in sugars between Environments I and III are not so marked but many of the data indicate a trend toward a lower sugar content in the fruit in Environment I.

SUMMARY

The influence of environmental temperature during the growing season on the development of bitter pit in the Gravenstein seems to be negligible. It may play a minor or indirect role in its development, but it is not as important a factor as certain metabolic conditions within the tree.

Growth, maturity, and sugar content of fruits were affected by temperature treatments but yet there were no significant differences in the amount of bitter pit.

It should be noted in this investigation, that the experimental environments included units of a single tree. Had whole trees been included in the various treatments, it is *possible* that the total effect of the different "climates" exerted on tree metabolism would have influenced the amount of bitter pit. Such an effect would be indirect and not a direct effect on the fruits themselves.

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Some Observations on Internal Cork Disease of Apples in Massachusetts¹

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DURING the season of 1936, an internal browning of the fruit of certain McIntosh and Cortland trees attracted considerable attention in Massachusetts. A striking example was noted in some Cortland and McIntosh trees in the State College orchard. Similar observations were made in at least a dozen orchards in different parts of the state. Since there is some confusion as to the name of this trouble, a brief discussion of the nomenclature seems to be in order.

This disease, or closely related ones, has been reported in the literature under various names. Mix (10) in 1916 described a disease which appears to be identical under the name cork. In 1918 Brooks and Fisher (4) also described a similar "disease or group of diseases" under the name cork. Rigg and Tiller (11) reporting from New Zealand in 1927 described similar diseases stating "In many ways, the symptoms and occurrence of the diseases resemble those of 'Drought Spot' and 'Cork' as described by Mix, Brooks and Fisher", but they do not themselves use any name. Latimer (6) in 1929, apparently following the nomenclature of Mix and of Brooks and Fisher, described the disease under the name cork. Burrell (5) reporting from the Champlain Valley in 1933 described a similar disease, using the name cork with reservations.

In 1928 McLarty (8) reported from British Columbia a disease, which, if not identical, is very similar, under the name corky core. He appears to have used this name solely because it was the local name for the trouble. In a later paper in 1936 (9) he used the same name. Young and Bailey (12) in a report from New Brunswick in 1936 used corky core.

In a report from New Zealand in 1935 Atkinson (3) described a similar disease to which he tentatively gave the name corky-pit. A few months later Askew (1), who cooperated with Atkinson, in a report on chemical investigations changed the name to "internal cork". In a more recent paper, Askew and Chittenden 1936 (2), the name "internal cork" was again used.

This variation in names is probably unavoidable in our present state of uncertainty as to whether different diseases or different manifestations of the same disease are being described. However, it is suggested that internal cork, as probably best describing the trouble, be used until further information shall suggest a more suitable name.

Internal cork was first observed in the College Orchard about September 1, but must have been present for some time previously. It is characterized by corky spots in the flesh of the fruit particularly around the core. (See Fig. 1.) This was accompanied in the case of Cortland by a roughness of the surface of the apple. No such roughness was noticed on McIntosh.

Observations were made of the amount of internal cork occurring

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in the fruit of two rows of apple trees standing side by side in the College Orchard. One is a row of McIntosh 39 years old, the other a row of Cortland 8 years old. These trees have been in sod for the past 10 years. A circular area extending to the tips of the branches was kept cultivated around the Cortland trees during the first 5 years in the orchard. Also in 1930 the entire orchard was plowed and reseeded



FIG. 1. Cortland apples showing internal cork.

at once to reestablish the sod. The trees have received an annual light dressing of poultry manure and a moderate application of a nitrogenous fertilizer, the amount for each tree being determined by its size and condition. These trees would rate medium to high in vigor. No cork has been observed before in the fruit of either row. Table I gives the results of observations in 1936 on these two rows of trees. The "per cent of apples affected" was obtained by cutting in half equatorially, 25

TABLE I—PERCENTAGE OF APPLES SHOWING INTERNAL CORK AND EXTENT OF INJURY

Tree Number	Treatment	McIntosh		Cortland	
		Apples Affected (Per Cent)	Extent of Injury	Apples Affected (Per Cent)	Extent of Injury
1	Sod	84	42	10	2
2	Sod	88	47	0	0
3	Sod	76	23	90	54
4	Sod	100	56	60	44
5	Sod	88	62	50	32
6	Mulch	4	1	0	0
7	Mulch	52	12	0	0
8	Sod	92	34	100	88
9	Sod	100	62	100	96
10	Sod	92	43	100	78
11	Sod	88	38	40	16

apples per McIntosh tree and 10 per Cortland tree. Any apple showing internal cork was considered affected. The extent of injury was obtained by rating the apples on the basis of 0 to 5; 0 = no internal cork, 5 = most severe internal cork, involving about 75 per cent of the flesh. The ratings of the individual apples on a tree were added and this total divided by the maximum total if every apple had rated 5. This quotient was then expressed as a percentage. This percentage gives an idea of the relative severity of the disease.

Trees 6 and 7 have been heavily mulched with hay for the past 2 years. Relatively little internal cork appeared in the McIntosh and none in the Cortland. There is some variability in severity among the trees in sod, particularly among the Cortlands. So striking was this difference between Cortland trees No. 2 and No. 9 that two trenches 5 feet long and $3\frac{1}{2}$ to 4 feet deep were dug one on the east and one on the west side of each tree. These trenches revealed in the case of:

Tree No. 9:—No roots below $2\frac{1}{2}$ feet. About 80 per cent of roots in top 18 inches. A fairly definite layer of roots at 6 to 8 inches. Strata below roots (C Horizon) mostly coarse sand and gravel.

Tree No. 2:—A few roots down to $3\frac{1}{2}$ feet. About 65 per cent of roots in top 18 inches. Much better distribution down to 2 feet than in tree No. 9. A B horizon 50 per cent deeper than in tree No. 9. Also slightly more clay in strata penetrated by deeper roots. Tree No. 2 is in a soil less likely to dry out during periods of drouth than tree No. 9. Also the deeper root system of tree No. 2 should enable it to withstand drouth better than tree No. 9.

Studies were made also in six orchards scattered widely over the state. In each orchard a trench 5 feet in length was dug beneath the branches of a typical tree showing serious internal cork. A similar trench was dug beneath a tree bearing normal fruit, the depth in each case being sufficient to expose the deepest roots. The trees were selected after cutting at least 10 apples. Fully recognizing the limitations of this method, we are led by our observations to believe that a trench of this kind provides same valuable information as to distribution of roots, nature of the subsoil, and consequently the moisture supply. After mapping the root distribution and measuring the thickness of the various strata, soil samples were taken for a later determination of water holding capacity.

In the following orchards, tree C indicates the tree showing internal cork, and tree N the normal tree. The terms A, B, and C horizon are used as described by Lyon and Buckman (7).

Orchard No. 2 (10-year-old Cortland), Tree C:—Very compact grayish layer below 2 feet. A few roots down to $3\frac{1}{2}$ feet but of uneven distribution. About 70 per cent of roots in top 18 inches. No earthworms observed. *Tree N:*—Soil fairly mellow down to $2\frac{1}{2}$ feet. Several earthworms found down to 2 feet. Good root distribution throughout B Horizon which was about twice as deep as that in Tree C. Only about 60 per cent of roots in top 18 inches.

Orchard No. 3 (8-year-old Cortland), Tree C:—No roots below 3 feet, with poor distribution below 2 feet. C Horizon made up of ex-

tremely porous sand and gravel. About 70 per cent of roots above 1 foot. *Tree N*:—Actual depth of rooting similar to *Tree C* but with less layering of soil in A and B Horizons. A stratum favorable for rooting at 2½ feet suggests a reserve moisture supply not apparent in *Tree C*. About 60 per cent of roots above 1 foot.

Orchard No. 4 (15-year-old McIntosh), Tree C:—Definite hardpan at 30 inches. No roots below that point. High water table in spring may be an important factor. *Tree N*:—No definite hardpan. A few roots just below 3 feet. Evidence of better aeration at 2 to 3 foot level than in *tree C*.

Orchard No. 5 (15-year-old McIntosh), Tree C:—Fairly definite hardpan at 32 inches. No roots below that point. Rather definite layering of roots above 1 foot. *Tree N*:—Rooting similar in depth to *tree C* but without the definite hardpan at 32 inches. Less layering of roots above 1 foot. A Horizon about 50 per cent thicker than in *tree C*. (The soil in this orchard is inclined to be too wet in early spring.)

Orchard No. 6 (7-year-old McIntosh), Tree C:—Impenetrable ledge just below 2 feet. *Tree N*:—No ledge. Some roots down to 3 feet.

Orchard No. 7 (20-year-old McIntosh), Tree C:—Impenetrable ledge at about 2 feet. Definite layer of roots just above ledge. *Tree N*:—Roots extend down to 5½ feet. Ledge at that level. Fairly good distribution throughout A, B, and C Horizons.

It will be noted in the above data that *tree C* has, in each case, a subsoil less favorable for deep rooting than *tree N*. The *C* trees were therefore more dependent on adequate rainfall during the summer.

TABLE II—RAINFALL IN INCHES AT AMHERST, MASSACHUSETTS AND DEPARTURE FROM NORMAL FOR 1936

Inches	April	May	June	July	August
Total Rainfall	4.07	1.76	3.28	1.45	4.85
Departure from Normal	+0.80	-1.87	-0.26	2.88	+0.61

Table II gives the rainfall and departures from normal at Amherst for the 5 months preceding discovery of the internal cork. The 5 inch deficit during May, June, and July, 1936 followed an annual deficit of nearly 9.5 inches in 1935. Also the number of hours of bright sunshine, number of clear days, and mean temperature were all above normal and mean relative humidity was below normal. All of these factors would contribute to the drying out of the soil. Weather conditions in other parts of the state, where internal cork was observed, were similar to those at Amherst.

DISCUSSION

Our observations show that this disease is not limited to any one soil type, it occurs where the subsoil is unfavorable for root penetration, and is partially prevented by a heavy mulch.

Whatever the cause for a shallower root system, such trees seem to be under a distinct handicap in a time of drought. They may be unable to obtain an adequate daily supply of moisture during a part of

the growing season. It is reasonable to assume that a fluctuation of this kind would prevent a normal development of the fruit.

This association of the disease with water deficiency has been reported by several workers (4, 5, 6, 8, 10, 11). Recent reports show that the use of boron has greatly reduced the incidence of this, or very closely related diseases (1, 2, 3, 9, 12). However, no data are available at present to show whether or not this trouble in Massachusetts can be remedied by applications of boron.

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Six Years' Records of Amount of Cork Spot Fruit on Individual d'Anjou Pear Trees¹

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IN cork spot of d'Anjou pears the dead, corky spots are beneath the skin or are deeply seated in the pulp and become obvious relatively late in the development of the fruit. The skin of mature affected fruit may have sunken areas about $\frac{1}{2}$ inch or less in diameter that show a somewhat darker green tint than the unaffected skin. These affected masses are also rougher, harder, and grittier than the normal skin. The cork spots may also be found scattered throughout the flesh, especially toward the calyx half, and are brown, dry, and corky. Brown, dry, corky tissue may also be found at the apical end, the region affected being comparable to that of the black end or hard end of Bartlett pears (3). Occasionally corky tissue may develop in the carpels of the core or in the region of the vascular strands leading from the stem to the core. Losses from cork spot in d'Anjou pears upon the *Pyrus serotina* rootstock have been serious in the central valleys of Washington, and as a result some orchards have been unprofitable. The disease is much less troublesome with pears grown upon *Pyrus communis* as a rootstock. The relations of rootstock and certain other factors have been previously reported by Overholser, Overley and Claypool (6).

EXPERIMENTAL DATA

The percentage of cork spot fruit produced upon the d'Anjou pear trees in the F. A. Norton orchard of Grandview, Washington (8) has been annually determined for the plot trees during 1931 to 1936 inclusive. This is an irrigated orchard with a sparse stand of alfalfa as a permanent cover crop.

Seasonal Variations:—It is commonly observed that the percentage of d'Anjou pear fruits that develop cork spot may vary considerably from year to year. It has been reported (6) that during the season of 1928 a considerable portion of the d'Anjou pear crop in central Washington was discarded because of cork spot. The seasonal variations in yield and in the percentage of cork spot developed in the fruit of the d'Anjou pear orchard under observation are shown in Table I.

TABLE I—ANNUAL VARIATION IN CORK SPOT OF D'ANJOU PEARS IN RELATION TO TOTAL YIELD PER TREE (AVERAGE OF 67 TREES)

Year	1931	1932	1933	1934	1935	1936
Average per cent of fruits with cork spot per tree	69	37	28	36	39	34
Average total number fruits per tree	376	291	984	630	854	430

The average percentage of the fruit that showed cork spot was highest in 1931 and the average total number of fruits borne that year

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was next lowest. The average percentage of cork spot fruit was lowest in 1933 and the average number of fruits borne per tree was the highest of any of the 6 years. This agrees with previous observations (6). It is also possible that the exceptionally high percentage of cork spot in 1931 to some extent may have resulted from the root and top injury experienced by the trees in 1930 (7).

Individual Tree Variation:—Growers have observed that certain d'Anjou pear trees seemed consistently to be relatively free from cork spot and other trees annually produced crops with rather high percentages of the fruits thus affected. For example, during the 1935 harvest the owner of the experimental orchard, marked trees which seemed to produce large amounts of cork spot fruit, with the intention of removing them. He verified his judgment of 1935 during the 1936 harvest season by re-marking almost every tree he had previously condemned. The data from plot trees for the past 6 years agree in nearly every case with the observations of the grower.

The data in Table II show the annual variation in percentages of cork spot fruit developed upon the five trees producing the lowest and upon the five trees producing the highest number of affected fruits.

TABLE II REPRESENTATIVE ANNUAL VARIATION IN PERCENTAGES OF CORK SPOT FRUITS PRODUCED BY INDIVIDUAL D'ANJOU PEAR TREES

Classification	Year and Percentage of Cork Spot Fruit Produced						Annual Average
	1931	1932	1933	1934	1935	1936	
<i>Trees Producing Low Percentages</i>							
R1—T19	29	10	4	2	3	4	6
R9—T10	34	5	8	2	19	5	11
R5—T4	16	7	11	0	0	6	6
R9—T8	30	12	7	3	5	5	9
R6—T9	21	20	8	6	6	1	9
<i>Trees Producing High Percentages</i>							
R5—T20	100	66	64	78	65	62	73
R6—T15	100	78	61	48	62	61	66
R9—T5	84	77	58	50	61	63	65
R10—T2	74	63	45	63	57	63	58
R10—T4	84	81	43	72	64	71	66

The representative data in Table II indicate that, while there are seasonal variations, nevertheless certain trees rather uniformly tend annually to average relatively low in the percentage of cork spot fruit produced, and certain other trees tend annually to produce relatively high percentages affected with cork spot. With occasional exceptions of a given tree for some particular year, this relationship held true for each of the 67 trees upon which records were obtained.

Extremes of Individual Tree Yields and Cork Spot:—Overholser, Overley and Claypool (6) reported upon the basis of field observations that when the crop borne was light, the percentage of d'Anjou pears affected with cork spot tended to be higher than when the crop of an individual tree was heavy. With the data for individual trees from the

Norton orchard the year of the largest crop borne by a given tree was compared with the year of the smallest crop as to the percentage of cork spot fruits produced, as in Table III.

TABLE III—THE APPARENT RELATION OF EXTREMES IN ANNUAL PRODUCTION TO PERCENTAGES OF CORK SPOT FRUITS DEVELOPED (REPRESENTATIVE DATA)

Plot		Highest Yields (Total Number Fruits)			Lowest Yields (Total Number Fruits)		
Row	Tree	Number of Fruits	Cork Spot (Per Cent)	Year	Number of Fruits	Cork Spot (Per Cent)	Year
1	18	1282	9	1933	222	43	1932
1	20	1305	4	1933	90	26	1932
2	4	1445	39	1933	435	44	1936
2	5	1224	9	1935	260	40	1936
5	3	991	37	1935	204	60	1936
5	14	1768	36	1933	449	86	1931
5	15	1832	22	1933	423	38	1936
6	4	1027	26	1933	418	54	1934
6	19	749	20	1935	133	40	1932

The data in Table III indicate, when the yield differences were relatively great, that on the year when the crop of an individual tree was largest, the percentage of pears affected with cork spot was lower than on the year when the smallest crop was borne. This does not mean, however, that the lowest crop year always coincided with the year of highest percentage of cork spot fruit, since occasionally the greatest percentage of cork spot fruit produced by a given tree occurred during another low crop year, but not the smallest crop year. The same relationship held with respect to highest yield and lowest percentage of cork spot.

Extremes of Percentages of Cork Spot and Yields:—The years when the highest percentages of cork spot fruits were produced upon a given tree were compared with the year when the lowest percentage developed as to differences in the amounts of fruits borne. Representative data are in Table IV.

The data in Table IV indicate that, with individual trees showing

TABLE IV—THE APPARENT RELATION OF EXTREMES OF PERCENTAGE OF CORK SPOT DEVELOPED TO ANNUAL PRODUCTION

Plot		Lowest Percentage of Cork Spot			Highest Percentage of Cork Spot		
Row	Tree	Cork Spot (Per Cent)	Total Number Fruit Produced	Year	Cork Spot (Per Cent)	Total Number Fruit Produced	Year
1	19	2	728	1935	29	241	1931
2	18	29	499	1933	100	244	1931
2	19	0	965	1934	52	401	1931
6	9	1	863	1936	21	498	1931
5	14	22	907	1936	89	701	1934
1	14	31	1165	1933	89	668	1934
9	4	5	969	1934	43	331	1932
1	9	33	1132	1935	75	290	1936
10	14	21	1240	1933	99	728	1935

wide variations, during the year the highest percentage of cork spot fruits was produced, the crop was lighter than during the year the lowest percentage of cork spot fruits was produced. The year of production of highest percentage of affected fruits did not, however, invariably coincide with the year of lowest production, since sometimes the largest percentage of cork spot fruit produced in a given year coincided with another year of relatively low production, but not the lowest. A comparable relationship also existed with respect to years of lowest percentages of affected fruits and highest yields.

With regard to the relation of years of extremes in production and percentages of cork spot, and also of extremes in percentages of affected fruits and yields, the conditions previously indicated existed with 47 out of a total of 64 trees. There were 17 trees with insufficient annual variation in yields or in percentages of cork spot fruits produced or in both, to show the correlations mentioned.

Relation of Tree Vigor:—The possible relation of tree vigor, as determined by annual increase in trunk circumference and average area of individual leaves during the years 1932 to 1936, inclusive, to the percentage of the fruits borne that were affected by cork spot is shown in Table V.

TABLE V.—THE APPARENT RELATION OF TREE VIGOR, AS MEASURED BY ANNUAL INCREASE IN TRUNK CIRCUMFERENCE AND AVERAGE AREA OF INDIVIDUAL LEAVES, TO CORK SPOT OF D'ANJOU PEARS (REPRESENTATIVE DATA)

Plot		Greatest Annual Increase in Trunk Circumference and Largest Area of Individual Leaves			
Row	Tree	Annual Increase of Trunk Circumference (Cms)	Average Area Individual Leaves (Sq. Ins.)	Cork Spot (Per Cent)	Year
1	9	4.0	3.64	75	1936
2	5	4.6	3.93	40	1936
5	5	3.3	2.73	84	1934
5	10	3.5	3.18	88	1935
6	19	4.9	2.78	40	1932
6	9	5.8	2.97	20	1932
9	3	5.4	3.84	37	1932
10	12	3.4	3.23	82	1936
10	17	5.0	3.20	69	1935

Plot		Lowest Annual Increase in Trunk Circumference and Smallest Area of Individual Leaves			
Row	Tree	Annual Increase of Trunk Circumference (Cms)	Average Area Individual Leaves (Sq. Ins.)	Cork Spot (Per Cent)	Year
1	9	2.7	2.83	33	1935
2	5	3.7	3.26	26	1932
5	5	1.7	2.49	25	1933
5	10	2.5	3.05	40	1933
6	19	3.5	3.02	7	1934
6	9	4.0	2.68	6	1935
9	3	3.6	3.43	5	1934
10	12	3.5	2.69	46	1932
10	17	3.3	3.91	18	1936

The representative data in Table V indicate that when the year of greatest trunk circumference increase and of largest size of individual leaves for any one tree was compared with the year of lowest trunk increase and of smallest size of individual leaves, the percentage of cork spot fruit produced tended to be higher in the season of the first instance and lower during the season of the latter instance. With records available for 62 trees, this was true for trunk circumference increase with 40 trees, and with the remaining 22 trees the annual differences either in trunk circumference increase or in percentage of cork spot were very small in 18, and relatively wide in only four instances. For the leaf size relationship to cork spot there were exceptions among the trees listed in Table V, namely, Row 10, Tree 17, and Row 6, Tree 19. With Row 10, Tree 12 there was a difference of one-tenth of one centimeter contrary to the general findings in relation to trunk circumference increase.

Since the d'Anjou pear trees were in a fertilizer experiment (8), it was believed of interest to contrast the two fertilizer plots showing the greatest difference in annual increase in trunk circumference, *i.e.*, the nitrogen plots and the phosphorus and potassium plots, as shown in Table VI. The nitrogen was applied as ammonium sulphate, phosphorus as treble superphosphate and potassium as potassium sulphate.

TABLE VI--THE AVERAGE ANNUAL PERCENTAGE OF CORK SPOT PEARS PRODUCED AND THE AVERAGE ANNUAL TRUNK CIRCUMFERENCE INCREASE OF THE TREES IN THE NITROGEN AND IN THE PHOSPHORUS AND POTASSIUM PLOTS

Plot	Average Per Cent of Cork Spot Fruit Produced per Tree						Average Annual Trunk Circumference Increase (Cms)
	1931	1932	1933	1934	1935	1936	
¼ pound actual N. annually applied per tree	79	49	37	44	39	40	4.5
1 pound each P ₂ O ₅ and K ₂ O annually applied per tree	59	19	14	30	23	18	3.0

The data in Table VI indicate that for the trees in the nitrogen plots, which made an average annual increase in trunk circumference of 4.5 centimeters, the average annual percentage of fruits affected with cork spot was 45; and for the trees in the plots receiving phosphorus and potassium, which made an average annual increase in trunk circumference of only 3.0 centimeters, the average annual percentage of affected fruits was only 24.

The difference in trunk circumference increase in the other plots receiving nitrogen in combination with phosphorus or potassium or both were not as marked as was the case with nitrogen alone, when contrasted with the phosphorus and potassium plots that made the least annual growth. Hence, the correlations were not so striking.

As in Table V the trees with most vegetative vigor, in this case those receiving nitrogen had the highest per cent of cork spot and those with less vigor, that is trees receiving phosphorus and potassium had fruit with the lowest percentage of cork spot.

McLarty (4) reported that additions of sodium nitrate or manure to good soils tended to increase the terminal growth and thus the leaf area and at the same time to increase the amount of corky core and drought spot developed.

In Table III it was established that during years of high yields the percentage of cork spot fruits was lower than during years of low yields. The trunk circumference increase and the average size of individual leaves for the same trees and the same years were examined, in an effort to reconcile the two. The trees included are the same as in Table III except 2-5 and 6-19, which are similarly contrasted in Table V.

The interrelation of high and low crop years, or low and high cork spot years (Table III) with years of vegetative vigor is shown in Table VII.

TABLE VII.—THE INTERRELATION OF HIGH AND LOW CROP YEARS OR LOW AND HIGH CORK SPOT YEARS WITH VEGETATIVE VIGOR

Plot		High Yielding and Low Cork Spot Years			Low Yielding and High Cork Spot Years		
Row	Tree	Average Size Individual Leaves (Sq Ins.)	Average Increase in Trunk Circumference (Cms)	Year	Average Size Individual Leaves (Sq Ins.)	Average Increase in Trunk Circumference (Cms)	Year
1	18	2.64	2.8	1933	3.51	5.0	1932
1	20	3.08	2.8	1933	3.19	4.7	1932
2	4	3.17	2.8	1933	3.91	4.7	1936
5	3	2.62	4.2	1935	3.49	3.8	1936
5	14	3.31	2.1	1933	—	3.4	1931
5	15	3.17	2.5	1933	3.55	4.9	1936
6	4	2.71	3.0	1933	3.04	—	1934

The data in Table VII indicate that the d'Anjou pear tree under irrigated conditions in central Washington tends to make less trunk circumference increase and to have smaller size of individual leaves during years when heaviest crops are produced than during years when lightest crops are borne, and thus the relationships shown between Tables III and VII might be expected. The one exception was with Row 5, Tree 3, in the case of trunk circumference increase.

DISCUSSION

Recently Askew and Chittenden (1), McLarty and Wilcox (5), and others have obtained evidence that "internal cork", "drought spot", and "corky core" of apples result from deficiency of boron. No experimental evidence, however, has yet been published indicating that cork spot of d'Anjou pears can be overcome by the use of boron. The authors have experiments under way to determine whether injection of boron compounds into the tree trunks or application to the soil under the trees will reduce the percentage of cork spot in d'Anjou pears.

If the trouble does result from boron deficiency, the relation of the rootstock *Pyrus serotina* may be due to a difference in the extent to which the two rootstocks may take up boron (2). The increase in

amount of cork spot that evidently results from root-killing might be explained on the basis of a reduction in the capacity of the tree for boron intake, as well as by a possible restriction in the soil mass from which boron might be taken up as a result of the lesser root area functioning. The seasonal variation might in part be accounted for by differences in yields and vegetative growth, as well as by the amount of boron that may be available from the soil. The greater vigor of growth, as measured by increase in trunk circumference, and the larger leaf area would increase the demand for boron and, limited amounts available, relatively increase boron deficiency.

That cork spot of fruit appears more serious during years of light crops might be related to the fact that on such years the trees tend to make greater trunk circumference increase and to produce leaves of larger average size, thus increasing the demand to a point that deficiency would be more likely to result. Askew and Chittenden (1) suggest that apple trees first meet the requirement of the leaves for boron and that in the case of deficiency, the fruits fall in boron content long before an appreciable decline can be noticed in the boron content of the leaves.

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Boron Treatment for a Physiogenic Apple Disease

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THE occurrence of drouth spot, internal cork, dieback and rosette presents a major production problem in certain apple orchards of the Lake Champlain Valley, where the author has been giving attention to these non-communicable troubles for the past 11 years. The present report deals with a few phases of this study. The only publication based on this work (8) presents evidence that the late-season form of internal cork is largely controllable by irrigation. However, details on earlier studies mentioned in the paragraphs which follow, are contained in the author's annual reports for 1926, 1927 and 1928 in the library of the Department of Plant Pathology or in a thesis (7) in the Cornell University Library.

SYMPTOMS AND THEIR MUTUAL RELATIONSHIPS

Drouth spot is a fruit symptom characterized by large more or less superficial necrotic areas which ultimately become russeted, retarded in growth and cracked. It usually appears before the fruit is half-grown. Drouth spot is sometimes confused with frost or spray injury.

Internal cork is characterized by masses of dead cells at any point in the flesh of the fruit. If it appears within about 6 weeks of petal-fall, the lesions become dry, corky and definitely delimited. If it is early and severe, the fruits may be badly distorted. If it appears in midsummer or later, the lesions are spongy rather than corky, their margins are less sharply defined and the affected fruits are normal or nearly so in shape.

Dieback refers to the presence of dead terminal shoots or spurs.

Incipient dieback is a new term proposed for a transitional symptom prominent in late summer as a result of processes leading to the death of twigs or spurs from the tip backward. It is characterized by reddening, bronzing and scorching of leaves, and death of tissue in the cambial region of the twig especially beneath the axillary buds.

Rosette refers to the presence of tufts of dwarfed, linear-lanceolate leaves at the tips of shoots otherwise bare, or to leaves of this character elsewhere on spurs or twigs. It is closely associated with dieback.

When fruit symptoms appear within 6 weeks after petal-fall, the type of symptom is fairly constant for any given variety. However, there are wide differences between varieties. Fruits of Tolman Sweet alone, among the sorts generally grown in the region, are consistently free from both drouth spot and internal cork, although Tolman Sweet trees, in rare instances, show rosette and dieback. The usual symptom on fruits of McIntosh, Northwestern Greening, Rome Beauty, Northern Spy, Winter Banana, Baldwin, Cortland and Lobo is drouth spot. The usual symptom in Fameuse, Rhode Island Greening, Duchess of Oldenburg, and Wealthy is internal cork. Northern Spy and Duchess of Oldenburg fruits often have both cork and drouth spot or a combination of the two; the same is true at times, of the other varieties.

When fruit symptoms appear during midsummer or later, the disease usually takes the form of internal cork in all varieties. Geographically, this form seems more widespread than the others.

Fruits affected with drouth spot or internal cork may drop at any time during the season; if they adhere throughout the summer, they ripen 1 to 2 weeks ahead of normal fruits. Dropping shortly before harvest is characteristic of fruits affected by the late-season form of internal cork.

There is strong evidence that drouth spot, internal cork, incipient dieback, dieback and rosette as occurring in this region, are symptoms of a single disease rather than separate diseases. This conclusion is based on the following observations.

1. The several symptoms usually occur in the same limited areas of certain orchards.
2. The development of drouth spot and of internal cork often is simultaneous.
3. Years when drouth spot is severe, the early season form of internal cork is likewise severe if suitable varieties are present.
4. The crop from a tree with incipient dieback or rosette almost invariably shows either drouth spot or cork according to the variety. Furthermore, the branches with incipient dieback or rosette are the ones with the highest incidence of drouth spot or of internal cork in fruits.
5. Intergrading symptoms on a given tree, branch or fruit often make a sharp separation between drouth spot and internal cork impossible.
6. The behavior of grafted trees supports this view. A tabular summary of some results of grafting experiments is given below. The grafting was done in 1927 and all scions have produced several crops of fruit except those on a Tolman Sweet tree which was winter-killed in 1933-34. Scions on this tree bore only two crops. The grafted trees are in a small area where fruit and vegetative symptoms of the disease were very severe at the start of the experiment. The table refers to the symptoms that developed within about 6 weeks of petal-fall of each year.

Stock Tree	Branches	Predominant Early Season Fruit Symptom
Fameuse	1. Ungrafted Fameuse 2. McIntosh scions 3. Cortland scions 4. Lobo scions 5. Tolman Sweet scions	Internal cork Drouth spot Drouth spot Drouth spot None
McIntosh	1. Ungrafted McIntosh 2. Fameuse scions	Drouth spot Internal cork
Tolman Sweet	1. Ungrafted Tolman Sweet 2. McIntosh scions 3. Macoun scions	None Drouth spot Drouth spot

This table shows that whether the disease took the form of drouth spot or of internal cork was determined largely by the scion variety. This was regardless of whether the stock variety was one subject to internal cork (Fameuse), to drouth spot McIntosh), or to neither (Tolman Sweet). Extensive field observations corroborate the results of these grafting experiments. It should be recalled that the drouth spot type of symptom is not usually produced after midsummer. If fruit symptoms appear after that date, a diffused form of internal cork with relatively little deforming of the surface, is the common form in all varieties.

Mix (15) working in the same territory, considered cork and drouth spot related, but probably not identical. Brooks and Fisher (5) working in the State of Washington, agreed with Mix. McLarty (12) referring to corky core (a form of internal cork), drouth spot and dieback states, ". . . the causes appear to be in some way associated."

EARLIER EXPERIMENTS WITH BORON

An irregularity in mineral nutrition was early suspected of playing an etiological role and plot experiments to test this hypothesis have been under way for varying periods up to 11 years. Only those pertinent to the present title will be summarized here.

In 1926, 1 pound of boric acid was spread under the drip of the branches of each of two 20-year McIntosh trees showing rosette and dieback as well as severe drouth spot. Although their condition improved rapidly, so did that of most surrounding checks; no conclusions could be drawn except that there was no injury. That same year, 1 per cent boric acid solution, injected rapidly during the growing season into freshly-cut stubs of vertical McIntosh branches caused some leaf injury. Again the checks failed to develop much disease. This scarcity of disease in checks was apparently due in part to an adequate water supply.

In 1927, a series of plots was laid out in a McIntosh block 7 years old in an area where drouth spot, dieback and rosette were expected to occur. This included soil applications of boric acid at the rate of $\frac{1}{2}$ pound per tree on four trees and 1 pound per tree on two trees. Treatments were repeated in 1928. The trees showed no injury. No symptoms developed in the area for several years; doubtless this is related to the occurrence of a series of rainy seasons. The significance of water supply will be covered more fully in a later report.

In 1933, a group of 64 young trees, mainly of the variety Fameuse, was selected for tests with fertilizers and other chemicals. The trees were just coming into production, had already shown some cork, and were believed on the verge of more, since the soil profile resembled that in outbreak areas. Each of eight scattered trees received $\frac{1}{4}$ pound boric acid crystals worked into the soil among the roots. In subsequent years, $\frac{1}{4}$ pound of boric acid per tree was applied in the same manner in the spring and again in the summer. No injury occurred, but there has been insufficient disease on the checks to date to permit of conclusions. This is probably due at least in part to a change from

clean cultivation to a sod mulch system of soil management, another point which will be amplified in a separate paper.

Ammonium sulfate and Chilean nitrate of soda applied to the soil have usually increased the amount of the various symptoms when trees have responded in yield and growth. In terms of the boron deficiency theory, perhaps the demand for boron at some critical period was increased by an amount greater than that supplied as an impurity in Chilean nitrate.

EXPERIMENTS WITH BORON IN 1936

With the stimulus of positive results in New Zealand (1, 3) and in Canada (10, 11), injection tests with boron and other chemicals were resumed. Both bearing and non-bearing trees were used.

In the bearing trees, the dry salt method described by Bennett (4) for injecting iron compounds, was followed. Holes $7/16$ inch in diameter were bored diagonally downward to a depth of about $2\frac{1}{2}$ inches in the crown. These holes were spaced from 3 inches to 6 inches apart around the circumference. Roughly 3 to 4 grams or $1/10$ to $1/8$ ounce of boric acid crystals was tamped firmly into each hole, filling it within about $1/2$ inch of the surface. The hole was closed with a water emulsion of asphalt. Unfortunately, a freeze on May 15, reduced the yield in these experimental trees to less than 5 per cent of a full crop. Some trees with a long record for production of drouth spot or of internal cork fruits, had only sound apples in 1936. However, the disease was light in the checks, so results were inconclusive as to fruit symptoms. There was little fresh development of rosette or die-back in checks surrounding the 25 mature trees receiving boric acid early in the season, making conclusions impossible on this point also.

However, one experiment was located in a block of McIntosh and Fameuse trees from 4 to 6 years old, where dieback and rosette were noted during 1934 and 1935. Rosette was already abundant on certain trees at petal-fall time in 1936. Some of the worst of these were chosen for treatment with boric acid. Others received zinc sulfate, while a few were marked as untreated checks. The injection method as just described for mature trees was followed except that there was only one hole per tree, the holes averaged only 2 inches deep and the dose was from 1 to 2 grams U.S.P. boric acid crystals, according to size of tree.

The results of this treatment are summarized in Table I. Since no response except slight injury was obtained from the zinc sulfate injections, these trees may perhaps be regarded as another series of checks.

The beneficial effects of boric acid are indicated by three different criteria in Table I. (a) Over 90 per cent of the twigs showing rosette before treatment subsequently developed normal leaves in the boric acid trees, while in the checks and zinc sulfate trees, recovery was negligible. (b) The development of incipient dieback was inhibited in trees receiving boric acid whereas this symptom developed copiously in the checks and zinc sulfate trees. (c) Having made a considerable amount of growth early in the season, the boric acid trees did not show appreciable second growth in August. In contrast, the checks and zinc sul-

TABLE I—EFFECT OF CHEMICAL INJECTIONS MAY 23 TO 28, 1936, ON ROSETTE, INCIPIENT DIEBACK AND ABNORMAL SECOND GROWTH OF YOUNG APPLE TREES IN THE CHAMPLAIN VALLEY

Row and Tree Number	Trunk Girth	Variety	Condition of Twigs				
			Before Treatment		Rosette Twigs Recovering (Per cent)	On August 10	
			Dead (Per cent)*	Rosette (No.)		Incipient Dieback (No.)	Second Growth (Per cent)*
Boric Acid							
16-35	8.75	Fameuse	20	62	77.4	0	1
17-24	8.25	McIntosh	10	133	96.2	0	0
17-27	8.00	McIntosh	60	221	93.2	2	3
19-24	5.25	McIntosh	70	33	100.0	1	5
19-29	5.50	McIntosh	80	138	100.0	3	5
20-32	5.50	McIntosh	80	167	98.2	0	0
21-21	4.00	McIntosh	50	80	100.0	4	0
41-40	6.75	McIntosh	70	111	92.8	0	5
42-27	9.25	McIntosh	50	103	97.1	0	5
42-33	7.75	McIntosh	60	77	100.0	0	1
64-25	9.50	McIntosh	20	97	68.0	3	0
70-18	9.50	McIntosh	40	113	79.6	0	1
Average	7.33		50.8	111.3	91.9	1.1	2.2
Untreated							
17-28	7.00	McIntosh	10	226	0.0	87	15
17-33	8.25	McIntosh	20	182	0.0	91	35
18-24	6.25	McIntosh	40	137	1.5	71	40
22-27	6.50	McIntosh	30	115	0.0	77	25
40-21	9.00	McIntosh	10	76	11.8	23	5
63-26	11.25	McIntosh	5	33	0.0	44	1
Average	8.04		19.2	128.2	2.2	65.3	20.2
Zinc Sulfate							
16-26	7.75	Fameuse	30	143	0.0	63	70
17-26	6.75	Fameuse	5	53	1.9	26	1
17-31	8.00	Fameuse	20	110	1.8	33	10
20-24	9.00	McIntosh	10	110	0.0	56	10
41-38	9.50	McIntosh	20	240	0.0	97	50
63-27	11.50	McIntosh	30	73	5.5	74	10
68-31	9.50	McIntosh	10	137	7.3	74	5
Average	8.86		1.79	123.7	2.4	60.4	22.3

*Estimated per cent of all twigs showing this condition. Other columns based on counts.

fate trees made little early growth but had a weak flush of growth in August, an evidence of disturbed physiology.

INJURY FROM BORON IN 1936 EXPERIMENTS

No foliage injury followed injection of dry boric acid crystals in either the mature or the young trees. Killing of cambium and bark for a fraction of an inch laterally from the hole, and a somewhat greater distance vertically, was general. This killing was probably due to boric acid, because the same sealing compound caused no such injury when used as a wound dressing or grafting compound. It may have been due to boric acid accidentally scattered during injection. If so it could perhaps be prevented by enclosing the boric acid in a capsule, or by compressing it into a cylinder similar to the common potassium hydroxide stick. It is believed that certain precautions helped prevent still greater injury. The downward slant of the holes made it easier to insert the crystals without scattering very much where it would come in contact with the cambium, and also reduced the outward flow in certain holes which accumulated free water from the wood. Placing

the crystals toward the center of the tree trunk reduced the likelihood of contact of the boric acid with the cambium. Sealing with asphaltum protected the cambium from water loss and from contact with dissolved boric acid.

About 300 other trees received injections of dry boric acid crystals at different dates during the summer and fall. In no case did foliage injury result, but the bark injury previously described as occurring around the hole, was common. Injection of $\frac{1}{2}$ liter of 1 per cent solution of boric acid in a hole bored in the trunk of a large apple tree resulted in no foliage injury in 1936, but similar injection of a 5 per cent solution caused the death of large branches.

Observations following spraying certain apple leaves with 1 per cent boric acid solution and others with 1 per cent household borax solution indicated that such leaves have a rather high tolerance for these chemicals. Results might have been different under different conditions. Preliminary tests of combining borax with the regular spray mixtures have since been mentioned by New Zealand workers (2).

Soil application of both borax and boric acid is being more extensively tested. Thus far no injury has been observed except severe leaf-scorching on some 12-inch seedlings which received 2 ounces of household borax per tree, an excessive application. Additional testing for possible injurious effects is imperative in view of the well recognized toxicity of boron compounds to many plants.

DISCUSSION

Since drouth spot, internal cork, dieback and rosette of apple in the Champlain Valley are believed to be symptoms of a single disease, the correction of vegetative symptoms indicates the probability of benefits in the case of fruit symptoms, particularly since more severe conditions seem required to produce dieback and rosette than to produce drouth spot and internal cork.

Information is fragmentary as to the respective causes of different non-communicable or physiogenic diseases of apple. Consequently, certain symptoms that may be distinct, have been grouped together in some publications. This situation has been mentioned by Brooks and Fisher (6). It would be unjustified to assume that all symptoms that have been regarded as related to internal cork or to drouth spot would necessarily respond to boron treatment. Rather, boron treatment may serve as a tool for the separation of some of these.

A case in point is the disease variously known as bitter pit, stippen or Baldwin spot. Internal cork has sometimes been considered merely a form of bitter pit. There is no published evidence that bitter pit is controllable by boron treatments. Its different symptoms, different geographic distribution, different response to water supply, different varietal susceptibility, and its occurrence independent of dieback and rosette all suggest that bitter pit is distinct from internal cork (7). However, boron treatments for bitter pit will be tested in 1937. McLarty and Wilcox (14) state, "The experimental results to date indicate that the boric acid treatment has no effect on the control of

this disease" (bitter pit). Their experimental evidence to support this conclusion presumably will appear shortly.

Certain cases of rosette in Western United States have responded to zinc treatment (9) but others have not. It is possible that some of the latter would respond to boron, especially those correlated in occurrence with internal cork or drouth spot.

SUMMARY

Evidence is presented to show that the drouth spot, cork, rosette, and dieback of the Lake Champlain Valley are different symptoms of the same disease rather than separate diseases. Injection of dry crystals of boric acid controlled rosette and incipient dieback in young apple trees. It is believed that drouth spot and cork, as occurring in the Champlain Valley will respond to boron treatments, because they are parts of the same symptom-complex. It does not follow that other physiogenic diseases such as bitter pit, would respond; some fruit symptoms often regarded as related to internal cork or to drouth spot may be of distinct origin. Most of the rosette symptoms of apple in western United States appear to be of different etiology from the rosette here discussed, although it is not impossible that certain cases may be the same as ours. Injury from boron supplied by different methods is discussed.

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Effect of Nutritional Treatments on Internal Cork of Apples

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INTERNAL cork of apples, sometimes termed deep drought spot has been reported from most apple growing sections of the world. It is characterized by brown areas deep in the flesh of the fruit. In mild cases, there may be no external symptoms. In severely affected fruit, the surface tends to be roughened or "pebbly" rather than smooth, and such fruit tends to color somewhat earlier on the tree. The discolored areas are mainly in the region of the stem in mild cases, but in badly affected fruit almost the whole apple may be affected. Internal cork causes considerable loss in apples and pears in the Pacific states, and in some apple varieties in the eastern states. In the Shenandoah-Potomac valley district, orchards of Ben Davis, Gano, and Oldenburg are most frequently affected.

Atkinson (1) in New Zealand, obtained control of internal cork in three apple trees previously badly affected by injecting dilute solutions of boric acid into the trunks. Analyses by Askew (2) indicated that the boron content of healthy apples was two to three times that of affected ones, and leaves from trees producing sound fruit contained almost double the boron found in leaves from trees producing badly affected fruit. Atkinson's results have been substantiated by work at the Summerland, British Columbia Dominion Experiment Station, (3) indicating that in British Columbia also, injection of boric acid into the tree, is effective in greatly reducing or preventing the development of what they term "corky core" and "drought spot".

EXPERIMENTAL PROCEDURE

In the spring of 1936, experiments were started to test the effectiveness of boron and a number of other inorganic materials in controlling internal cork and other physiological disorders near Martinsburg, West Virginia in the Shenandoah valley. For the work with cork, a block of Ben Davis trees about 30 years old was used. They were growing in a soil classified as Frankstown gravelly silt loam. Erosion had removed most of the surface horizon. The trees had been well fertilized with nitrogen. The pH of the surface soil was about 7.2 while that of the "B" horizon was about 6.9. These figures indicate rather heavy liming in the past, as this soil series normally is moderately acid.

The amount of internal cork developing in the fruit of these trees in previous years is not known. It had been so severe in recent years that little fruit had been packed from the plot. Individual trees varied widely, however, in the amount of cork in the fruit.

The treatments received and location of treated trees are indicated in Fig. 1. Each of the plots extended from top to bottom of a rather gentle slope, and there was no evidence of any difference either in soil condition or in tree vigor or appearance in any of the plots. The treatments consisted of magnesium sulphate 5 pounds per tree; manganese

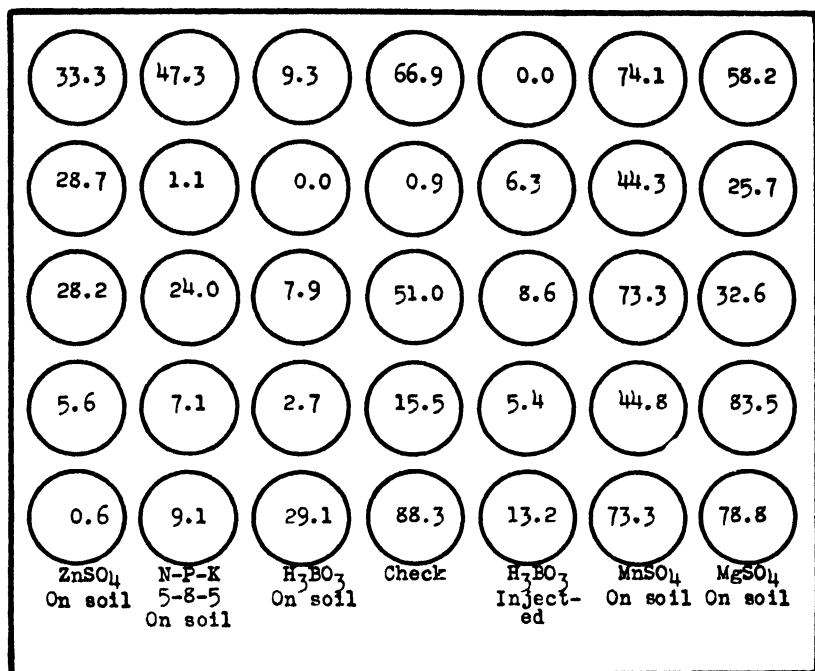


FIG. 1. Chart showing treatments applied, arrangements of plots, and figures in circles indicating the percentage of fruit showing internal cork in any degree.

sulphate 1 pound per tree; 5-8-5 fertilizer 10 pounds per tree; zinc sulphate 5 pounds per tree; boric acid 1 pound per tree. The foregoing materials were applied to the soil under the spread of the branches. In an additional plot boric acid U. S. P. fine crystals was "injected" into the tree trunk in the following manner: Holes were bored with a $\frac{3}{8}$ inch bit to a depth of 2 inches at five places about equidistant around the trunk of the tree. Three grams of boric acid were placed in each of the five holes and a cork inserted. The hole was then covered with grafting wax. By this method the boric acid was placed in the younger portion of the xylem. All applications were made on April 8, 1936, about 20 days before full bloom.

Observations throughout the summer showed no injury to the vegetation around the trees as a result of the application of any of the materials. The boric acid placed in the tree trunk resulted in some injury. By the middle of the growing season the bark was killed in an area extending about $\frac{1}{2}$ inch to 1 inch on either side of and from $2\frac{1}{2}$ inches below to about 4 inches above the hole. This killed area did not extend appreciably further during the latter half of the growing season. The extent of wood killing has not been determined. At harvest time approximately half the boric acid remained undissolved in the holes. When the fruit was picked, 100 to 200 apples were selected at random

from each of the 35 trees. Each of the apples was examined by cutting and classified according to the amount of cork present (Fig. 2).

DISCUSSION OF RESULTS

Because of the considerable variability between individual trees in the amount of cork present, the percentage of the fruit showing any cork for each of the trees is presented in Fig. 1. In Fig. 2, the average amounts of cork for each plot are shown graphically, together with the degree of severity of the condition. Trace cork indicates only one to three areas in the flesh near the stem. Medium cork indicates several areas, but the discoloration was limited to the stem end one-third of the fruit. Bad indicates cork areas extending to the middle line of the fruit or beyond, while very bad represents practically the whole interior of the fruit discolored. Fruit listed as bad or very bad should not be packed in any grade.

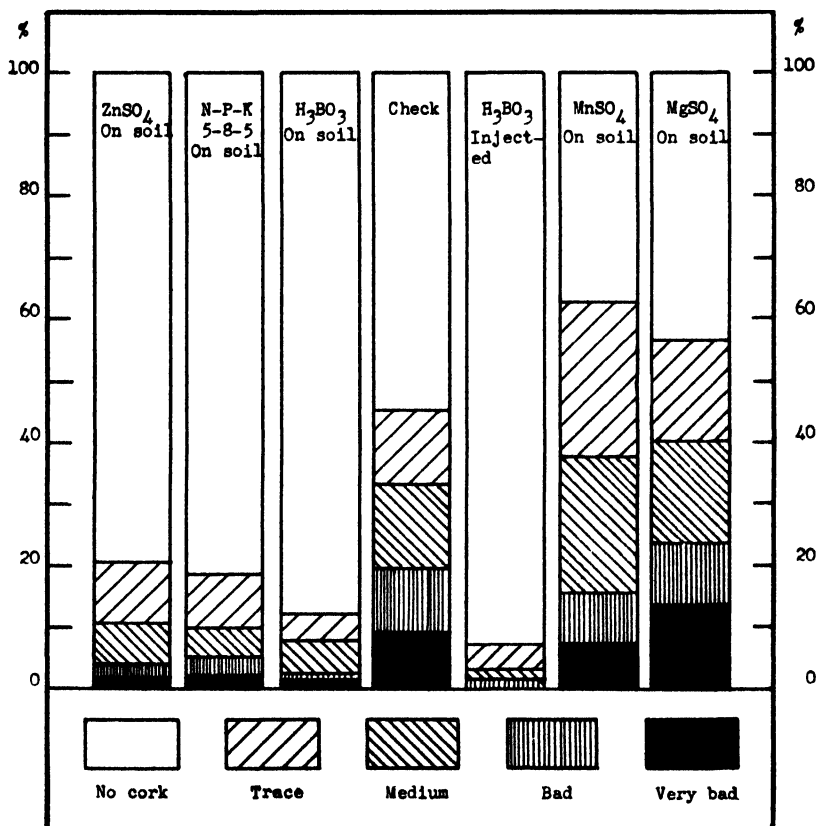


FIG. 2. Graph showing average percentage and severity of internal cork following the different treatments.

It is apparent from Figs. 1 and 2 that the plots receiving boric acid, either injected or applied to the soil, showed the least cork development. Almost equally free of cork were the complete fertilizer and the zinc sulphate plots. The check, manganese sulphate and magnesium sulphate plots were much more severely affected. The fact that the check shows slightly less cork than the manganese and magnesium plots probably is not significant, as one tree in the check plot was practically free of cork. The average of the other four trees shows as severe cork as the manganese and magnesium plots. In the trees showing a small amount of cork, this was usually limited to fruit from an occasional branch. A few branches occurred in the boron plots which bore corky fruit. Possibly boron had not been carried to these particular branches.

pH readings taken after the end of the growing season showed no significant effect of the materials applied on the soil acidity, with the possible exception of the zinc sulphate. The "B" horizon of that plot showed a pH of 6.5, the highest acidity of any plot. All pH readings were made by the glass electrode method.

These preliminary results are presented at this time because of the economic importance of internal cork. They indicate that boric acid crystals placed in the trunk, or larger applications made on the soil are beneficial in reducing cork under the conditions found in the Shenandoah valley, and support results in New Zealand and British Columbia. A complete analysis of the 5-8-5 fertilizer used has not yet been made, and it is not known whether results obtained with this material may be due to boron content or not. In the case of zinc sulphate, soil acidity appeared to be affected in the "B" horizon, and this may affect boron availability. On the other hand, zinc deficiency also is a possibility in these plots. The trees receiving zinc sulphate looked particularly thrifty during the middle of the growing season. A number of the trees showed "rosette" and die-back symptoms, typical of those corrected by zinc in the Western States. There is also a possibility that the zinc sulphate and complete fertilizer plots, located on one extremity of the experimental area were less affected by internal cork prior to treatment.

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Little-Leaf or Rosette of Fruit Trees

VI. Further Experiments Bearing on the Cause of the Disease

By D. R. HOAGLAND, W. H. CHANDLER and P. R. STOUT,
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IN the report of last year, greenhouse experiments with a subsoil from a diseased peach orchard were described. Evidence was presented that this soil had a toxic effect on plants representing a number of species and that apricot seedlings developed typical "little-leaf" symptoms, which were completely prevented by the application of zinc sulphate to the soil. Similar symptoms were produced when plants were grown in nutrient solutions sufficiently low in zinc. During the past year, we have continued these experiments utilizing another lot of soil from the same tract of land.

The recent experiments have been concerned primarily with effects of soil treatments on the maize plant. Confirming the observations previously reported, "white-bud" disease occurred and was prevented by the application of zinc sulphate, but not by the application of sheep, chicken, or cow manure low in zinc. Some of the beneficial effects of applications of sheep manure on other species of plants as noted in experiments with the first lot of soil employed may have resulted from the sulphate content of the manure, but in the work of the past year the soil has been treated with calcium nitrate, potassium phosphate and magnesium sulphate, and still characteristic symptoms of disease have appeared on maize, apricot and cotton plants, and on tomato plants in an early stage of growth. The severe injury to tomato plants observed last year did not recur. No opportunity has been afforded to study other species systematically in this series of experiments. It should be added that, under our greenhouse conditions, sheep-manure has not prevented the disease in apricot seedlings.

We have suggested from time to time the hypothesis that a soil biological factor might form one link in the chain of events leading to the production of the "little-leaf" disease, at least under California conditions. With this idea in mind, we have treated the disease-producing soil by various procedures designed to have effects on soil organisms. Sterilizing the soil in an autoclave (three successive heatings for 7 hours at 15 to 18 pounds pressure with 1 week intervals between sterilization) was completely effective in preventing the appearance of disease in the maize plant. Steam sterilization of the soil might, of course, have produced its effects through chemical reactions of the mineral constituents of the soil liberating zinc to the soil solution, quite apart from any biological effects. This conclusion was made less probable by the observation which was also made that treatment of the soil with formaldehyde or ether (the experiments with ether were made by Dr. P. A. Ark), likewise made possible the growth of healthy maize plants. Especially pertinent to the point, however, are the results of several experiments which showed that a small amount (1 or 2 per cent) of unsterilized soil mixed with the sterilized soil reestablished

the toxic condition and this could be again overcome by suitable additions of zinc sulphate to the soil.

Mention may also be made of other experiments which have not yet been repeated. Apricot seedlings and corn plants were grown in tanks of the "little-leaf" soil between alfalfa plants which had been established for about a year. The growth of the apricot and corn plants was retarded in comparison with the growth occurring in soil treated with zinc sulphate but the "little-leaf" and "white-bud" symptoms were almost entirely absent from the plants grown in association with alfalfa. The corn and apricot plants in the control tanks were markedly affected with symptoms of the disease. As in last year's experiments alfalfa has shown no evidence of disease when grown in the soil producing "little-leaf" of apricot seedlings. It is clear that the alfalfa can absorb from this soil an adequate amount of zinc for its metabolism. In one experiment, in which two successive crops of corn were grown, large applications of urea, (much larger than would be used under field conditions), in some way altered the soil to remove its power to produce disease. In another experiment the roots of a tomato crop were allowed to decompose in the soil. The second crop of maize following the tomato crop was free from symptoms of disease, although growing successive crops of maize alone has often caused some unfavorable condition in the soil to become accentuated. Finally, attention may be called to the fact that light and temperature conditions greatly influence the effects produced on plants either by the soil or by solutions deficient in zinc.

One of us (P. R. Stout) has developed a method for determining zinc in plant tissues based on a separation with dithiocarbazone reagent, followed by estimation of zinc by the polarograph. This method has given more satisfactory results than methods previously used in this laboratory. Small amounts of zinc may be determined within an error of ± 5 per cent. Many analyses of plant tissues from plants grown in the controlled experiments and from trees in the orchard have become available. The general indications of these analyses are that typically diseased plants are nearly always relatively low in the percentage of zinc present, but there was not found otherwise an invariable consistency between zinc content and the condition of the plant. It must be emphasized, however, that it may not always be possible to draw correct inference from the percentage content of zinc in plant tissues sampled at a single stage of growth. Perhaps zinc percentages should be based on some fraction of the plant tissue, such as protoplasmic nitrogen, rather than on the whole tissue, including cellulose. The total amount of zinc absorbed from a given mass of soil, as distinguished from the percentage of zinc present in the plant, may sometimes be the safer basis for interpretation in terms of zinc deficiency. On the other hand, a larger total amount of zinc might be absorbed by a plant incidental to the increased growth resulting from the removal of a toxic condition. It is difficult from zinc analyses alone to decide between cause and effect.

Delay was experienced this year in starting experiments with apricot seedlings and we have as yet no direct evidence that some of the treatments effective with maize or other annual plants will also be effective

in preventing "little-leaf" disease in trees. However, it is difficult to assume that zinc would be a corrective for entirely unrelated disorders produced by the same soil under the experimental conditions employed. What, if any, secondary factors may have been significantly operative we do not yet know. This must be regarded as a progress report.

Our data obtained in the experiments of the past 2 years are not inconsistent with the view that the "little-leaf" or related diseases, have as an immediate cause zinc deficiency, and, in fact, they point to this conclusion. At the same time there is evidence that in some, if not all cases, soil microorganisms may intervene to bring about the zinc deficiency in the plant. The possibility that direct toxic effects may also be present in the most severe forms of the disease is not excluded.

Experiments on the Treatment of Mottle-leaf Of Citrus Trees. III¹

By E. R. PARKER, *University of California, Riverside, Calif.*

AS a part of a research program (3) concerning the responses of citrus trees to zinc applications, a large number of trees have been treated under a wide range of conditions in southern California (4). Trials have been conducted in a large number of commercial orchards with various variety and rootstock combinations, upon different soil types, and in several climatic zones of southern California. Cultural practices have varied considerably in these orchards, but owing to the interaction of other factors the responses of trees under specific cultural programs could not always be compared.

An exceptional opportunity to obtain information regarding the zinc responses of trees under varying fertilizer programs resulted from the decision to treat half of each plot in the comprehensive fertilizer trial with oranges at Riverside (1). This experiment has been in effect since the spring of 1927. Each plot consists of eight Washington Navel orange trees in a single row. The plots are separated by suitable guard rows. There are 43 fertilizer treatments (four plots each) and 1 treatment of 25 plots. The results obtained from the various fertilizers showed, prior to zinc treatment, a yield response to nitrogen and organic matter applications.

Since mottle-leaf is most severe during late winter, and since new growth is absent at that time, comparisons can be more critical than at other seasons. Hence, tree-condition surveys were made during the late winter of each year. The judgment of two or more men² was averaged at each inspection. It was found that the individual opinions agreed very closely. This judgment was based upon the extent of mottle-leaf and the thrift of the trees. In most cases these two criteria led to identical conclusions. This was particularly true in the case of plots receiving equal amounts of nitrogen. The results of the surveys were reported in five relative terms, plus and minus signs also being employed. These relative gradations have since been given an arbitrary numerical rating on an index scale ranging from 10 to 90, as follows: excellent, 90; good, 70; medium, 50; poor, 30; very poor, 10. The addition of a value of 7 for a plus and the subtraction of 7 for a minus classification of each grade was made. For the present analysis of the effect of zinc applications, only 32 treatments involving 149 plots which received 1 pound of nitrogen per tree annually are considered.

Zinc treatment of the four trees of each plot row of all treatments nearest the irrigation pipe line was first made in March, 1934, when the earliest buds were opening. The application consisted of 10 pounds of $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$, 5 pounds of $\text{Ca}(\text{OH})_2$ and 4 ounces of powdered

¹Paper No. 365, University of California Citrus Experiment Station and Graduate School of Tropical Agriculture, Riverside, California.

²The survey was conducted in 1932 by Gordon Surr, L.D. Batchelor, and Parker; in 1933, by Surr and Parker; in 1934, by O. L. Braucher, F. Hagen, and Parker; and in 1935, by Hagen and Parker.

blood albumin spreader to 100 gallons of water. The four remaining trees at the lower end of the irrigation run were left as controls.

A decided improvement in tree condition soon after zinc treatment was evident. Many treated trees showed a decrease of mottle-leaf and increased vigor by June, 1934. In some instances a small amount of the spray fell upon the leaves of the upper tree of the checks, since it was impossible to prevent all drift of the mist of the spray. This deposit visibly affected some "untreated" trees and to that extent decreased the reliability of future comparisons.

The effect of the zinc treatment on tree condition is indicated by the mean values of the tree-condition indexes for each of the 32 fertilizer treatments for the 3 years prior to zinc treatment, and for the treated and untreated areas 1 year after zinc application. These were as follows:

Mean index for 3 years, 1932-34, prior to treatment....42.3

Mean index for untreated area, February 1935.....53.3

Mean index for treated area, February 1935.....79.4

This striking improvement in tree condition appears more significant when it is realized that tree improvement was evident without exception in the zinc-treated area of plots devoted to all fertilizers which supplied equal amounts of nitrogen. Within a year all treated trees in such plots assumed a more normal foliage and satisfactory vigor. The extent of improvement was greater on trees which had been more severely affected by mottle-leaf. Furthermore, the improvement of trees treated in 1934 was maintained throughout the year 1935-36.

Observations have been made on the mean effects of zinc treatment upon yield of fruit set in the spring of 1934, the season of treatment, and also in 1935. Since the area of each plot treated with zinc in 1934 was nearest the irrigation distributing line, it was thought advisable to adjust the yields for systematic errors which may be introduced by this fact. Accordingly, the yields which follow have been adjusted according to their regression upon the mean yields of the same trees in the 2 years prior to zinc treatment, that is, the crops set in 1932 and 1933. The methods of covariance as given by Fisher (2) have been used. In addition, the areas left for checks in the zinc treatment of 1934 were treated in March, 1935, with the same spray material first used. This was done in order that difficulty in the irrigation of trees which had been originally treated and the original controls might not compli-

TABLE I—MEAN ADJUSTED YIELD PER TREE OF 32 FERTILIZER TREATMENTS RECEIVING ONE POUND OF NITROGEN PER TREE EACH YEAR*

Crop Set in Spring of:	Yield (Pounds per Tree)		
	Treated with Zinc, March, 1934	Check (Treated with Zinc, March, 1935)	Difference
1934.....	156.5±2.02†	147.0±2.02†	9.5±2.85†
1935.....	120.8±1.53	98.1±1.53	22.7±2.16

*The treatments include 31 of 4 plots each, and 1 of 25 plots.

†Probable error.

cate the fertilizer experiment. The effect of the 1935 treatment of the checks gave satisfactory results and probably affected the yields of 1935, thereby reducing the increase recorded as a result of the 1934 zinc treatment.

Table I indicates that an improvement in yield of about 6.5 per cent resulted from the treatment in the crop set after treatment in 1934. The trees treated in 1934 showed in 1935 an increase in yield of 24 per cent over the trees treated just before the 1935 crop was set. The increase in yield of Washington Navel oranges was much greater in the second season after treatment than in the first season. In this respect, the response has differed from that obtained in other of our trials with citrus trees, for in some cases a large increase in yield has resulted in the first season from treatment just prior to blooming.

Further analysis of the yield responses to zinc treatment show that the adjusted yields of the 1934 crop were higher in the case of the zinc-treated areas in 25 out of 32 fertilizer treatments involving the application of 1 pound of nitrogen per tree. The 1935 crop was increased in 30 out of 32 fertilizer treatments by zinc treatment in 1934, and was almost equal in the other two treatments. There was, moreover, a tendency for the most severely affected trees to show most improvement in yield, as well as tree condition, as a result of zinc treatment. This may be illustrated by correlating the increase in adjusted yields as a result of the zinc treatment with the mean tree condition of 1932-34. The following coefficients of correlation are obtained: for the crop set in 1934, $r = -.24 \pm .05$; for the crop set in 1935, $r = -.48 \pm .04$.

It seems evident that zinc treatment is effective on mottle-leaf under a wide range of fertilizer programs, and that mottle-leaf has been an important factor in this orange fertilizer experiment. The improvement in the condition of the trees, and in their yields, subsequent to zinc treatment indicates that, at least in general, the fertilizer treatments studied (1 pound of nitrogen annually per tree, from various sources and with various additions) have not in this trial been capable of promoting normal tree development and yield. The uniform treatment of all plots with zinc is believed justified as a means of promoting more normal tree behavior in order that the specific effects of the various fertilizers can be more accurately determined.

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Little-Leaf or Rosette of Fruit Trees. VII. Soil Microflora and Little-Leaf or Rosette Disease

By P. A. ARK, *University of California, Berkeley, Calif.*

THE possibility that the soil flora might play a certain role in the production of the "little-leaf" disease complex has been apparent for some time (1). The soil microflora of orchards in which the "little-leaf" is especially severe has been studied in some detail during the past two years.

BACTERIOLOGICAL EXAMINATION OF SOILS

Two methods most commonly used by the soil microbiologists, *i.e.* the slide method of Cholodny (2) and the dilution plate method with many kinds of media, were employed in the exploration of a soil bearing normal plants and one producing "little-leaf" plants.

Slides used for the Cholodny method were thoroughly cleaned and disinfected by dipping into 95 per cent alcohol and flaming over the Bunsen burner. In handling slides in the field the technique as described by Cholodny was followed in all details. The slides were inserted in the soil about 1 foot below the surface and usually close to the roots. The slides were changed at monthly intervals for a 12-month period. Rose-Bengal stain was used in staining the slides. Samplings of the soil into which the slides were inserted were made and after delivery to the laboratory were plated in organic and synthetic media. There was a close agreement in the final results between the slide and the plate methods. From the data obtained it appeared that the soil microflora in the affected orchard is predominantly bacterial while in the healthy orchard fungi are much more in evidence.

The water extract of the little-leaf soil was found to be toxic to detached apple shoots. The alcoholic and ether extracts of the same soil were injurious to corn plants grown in a complete culture solution and this was corrected by application of zinc to the solution or into the plant (Fig. 1).

Little-leaf soils incubated under partially anaerobic conditions became very toxic to corn, tomato, cotton and peach plants. Sterilization by steam destroyed that toxicity and made these soils fit for a normal growth of plants mentioned above.

Since there was established a striking difference in the microflora of the root zone between the healthy and diseased plants it was interesting to learn the effect of that soil on plant growth after killing all or most of the microorganisms. Therefore the "sick" soil was sterilized by three methods: (a) by steam, (b) by formalin and (c) by ether. Soils from two different orchards were used in the experiment. The first soil was from an orchard at Delhi, California, where peaches were in a very bad condition from the little-leaf disease, and was taken from depths of from 3 to 6 feet. The second soil was from Sebastopol, California, from an apple orchard very severely rosetted and from 2 to 4 feet in depth. The soils were distributed in one-gallon glazed jars.



FIG. 1. Effect of the alcoholic extract of Delhi region soil (where little-leaf occurs) on corn plants in complete culture solution. Two plants on left were treated with the extract. Two plants on right are checks (untreated). The plants were set Oct. 23, 1936, photographed Nov. 23, 1936.

When the soils were steamed at 15 pounds pressure for 4 hours on each of 3 consecutive days and then allowed to rest for 2 weeks, the soils were found to be still injurious to the annuals used in the experiment (cotton, tomato, sunflower and corn). Sterilization for 3 days, 8 hours a day, at a pressure of 20 pounds was effective in correcting the unfavorable condition and plants grown in soil thus treated were healthy, while those grown in the original (untreated) soil were severely injured.

Formalin sterilization consisted in adding 100 cc of commercial formalin (40 per cent strength) to each gallon of soil, covering it tightly for 2 days and then allowing the formalin to disappear completely before planting. To sterilize with ether 200 cc of ether was poured into a gallon of soil, the container was closed very tightly and left in the greenhouse for 7 days after which the container was opened and planted after complete evaporation of the ether. Both formalin and ether corrected the soils. Figs. 2 and 3 show this effect on tomatoes and corn plants.

To study further the probable relation of the soil microflora to the disease, soils previously sterilized by steam or formalin were recontaminated with small quantities of the original soil (from 25 to 100 gms



FIG. 2. Tomato seedlings grown in Delhi (little-leaf) soil. Left, soil treated with ether; right, check (untreated soil).

per gallon of soil). These were left in the greenhouse for 2 weeks, being kept moist with distilled water. Plants developed from the seed sown in these soils were very much depressed and similar to those in the non-sterilized soil. This was taken to mean that the microorganisms present in the original soil multiplied in the sterilized soil and produced a condition unfavorable for the normal development of plants.

In another experiment the little-leaf soil was inoculated into quartz sand cultures and corn seedlings planted in them. The zinc content of the

culture solution was very low. The plants in the sand culture plus non-sterilized soil soon developed white bud symptoms, while corn plants in the sand culture to which sterilized soil was added, and in the pure sand culture without any little-leaf soil, remained normal for a period of 6 weeks. The results of these experiments seem to parallel those of Gerretsen (3) where the soil microflora shows a definite relation

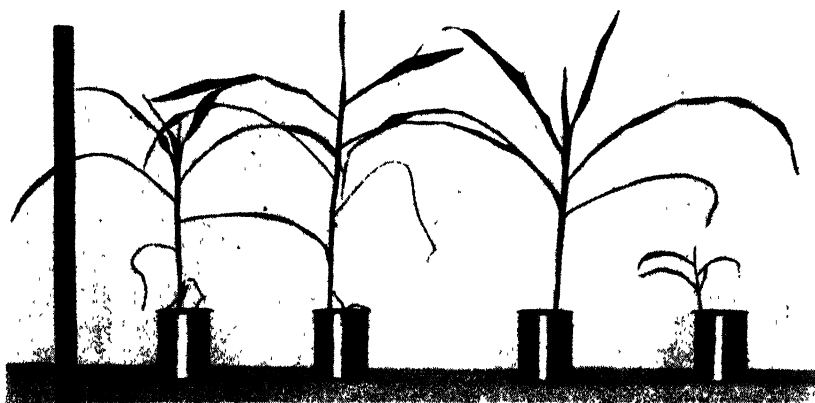


FIG. 3. Corn plants grown in Delhi (little-leaf) soil. Left to right: steam sterilized; formalin sterilized; ether sterilized; check (untreated soil). Planted Sept. 26, 1936. Photographed Nov. 3, 1936.

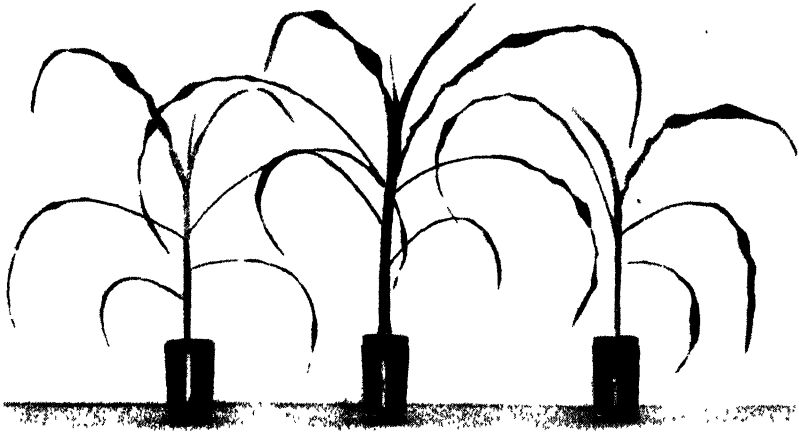


FIG. 4. Effect of culture 2722 on corn plant. Plants on each side were grown in culture solution plus bacterium 2722. The center plant is the check. Note chlorosis and striations on inoculated plants.

to the symptoms of the grey speck disease of oats, and also with the experiments of Shear (4) on sterilization of soils in which frencing of tobacco occurs, and Spencer (5) on inoculation of sand with the small quantities of such soil.

EXPERIMENTS WITH BACTERIA FROM SOILS OF AFFECTED ORCHARDS

The direct plating of soil samples taken from the root zone of dis-



FIG. 5. 1, 2, and 3, corn plants grown in the formalin-sterilized soil. 4, 5, and 6, corn plants grown in the formalin-sterilized soil to which a small quantity of the original (non-sterilized) soil (little-leaf) was added.

eased plants yielded a variety of bacterial species. It was noticed that three species of bacteria were especially numerous on plates and appeared rather consistently. These bacteria were studied in their relation to plants by inoculation into sterilized or non-sterilized soil. The three bacterial cultures were designated as Chr, D16 and 2722.

The sterilized and non-sterilized Delhi soil was distributed in tin cans (No. 1 and No. 2) painted inside with asphaltum paint. Some of these cans were inoculated singly and some in combination with other bacteria and some left without inoculation as checks. Seeds of Golden Bantam corn were planted 2 weeks after the inoculation.

In soils treated separately with the organisms designated as D16 and 2722 or with a mixture of D16 and 2722 the corn seeds germinated very slowly in comparison with checks (in treated soils) and were very stunted and chlorotic (Fig. 6). Plants grown in a mixture

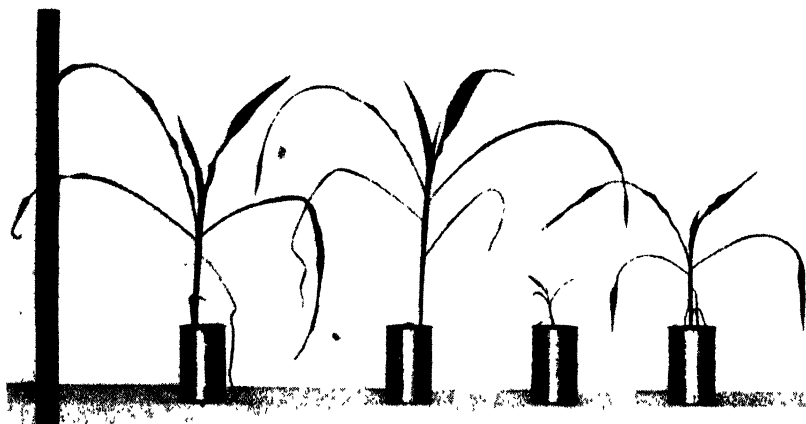


FIG. 6. Left to right. 1, corn plant in sterilized (Delhi, little-leaf) soil; 2, corn plant in sterilized (Delhi, little-leaf) soil plus bacteria 2722 and D16 and then resterilized; 3, corn plant in sterilized soil plus bacteria D16 and 2722; 4, corn plant in sterilized soil plus bacteria 2722 and Chr. Planted Sept. 26, 1936. Photographed Nov. 6, 1936.

of 2722 and Chr grew even better than in the checks (untreated soil). When inoculated into a complete culture solution containing 0.023 ppm of Zn the cultures D16, 2722 and mixture of D16 and 2722 induced the symptoms of white-bud (Fig. 6). This condition was consistently corrected by increasing Zn in the culture to 0.046 ppm or by injecting zinc sulphate into the stem of the plant.

Preliminary tests with seedlings of peach grown in sand culture (Fig. 7) and walnut grown in Delhi soil inoculated with the organism 2722 have resulted in symptoms very similar to those of little-leaf in the field. The appearance of these symptoms was prevented by the presence of zinc.

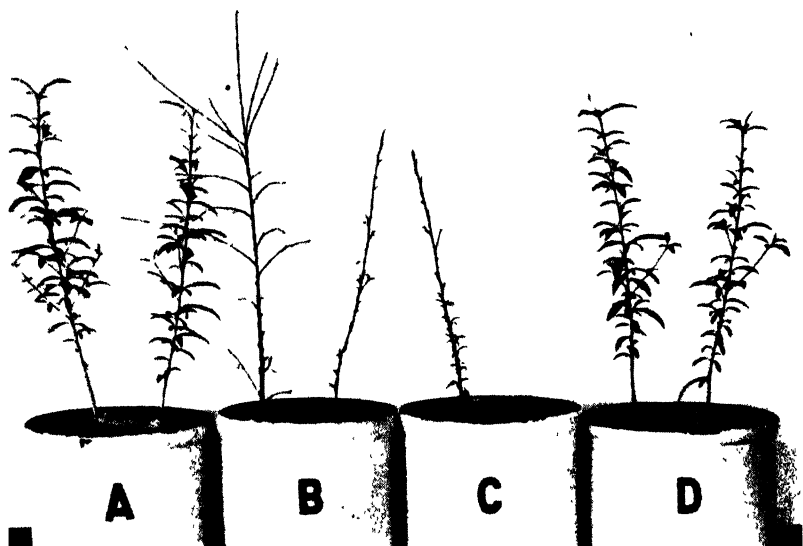


FIG. 7. Peach seedlings (Lovell var.) grown in Belgium sand to which complete Hoagland's solution was added. A and D, controls; B and C, sand treated with the bacterial culture 2722

ACKNOWLEDGMENTS

The author wishes to express his appreciation to Professor D. R. Hoagland and W. H. Chandler for suggesting the problem and for their interest and cooperation. The author is also grateful to Professor R. E. Smith for his constant interest in the problem and occasional suggestions in the course of the work, and to Dr. H. Earl Thomas for much help throughout the work.

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The Translocation of Mineral Elements in Plants

By OTIS F. CURTIS, *Cornell University, Ithaca, N. Y.*

ABSTRACT

This material will be published in full elsewhere.

MY earlier investigation demonstrated that ringing of woody stems, though not entirely preventing upward transport of nitrogen and ash constituents, usually greatly interfered with such upward movement. This led to the conclusion that mineral salts under natural conditions are carried perhaps chiefly in the phloem tissues. Although the evidence for upward translocation of minerals through the phloem is very strong there seems to be no previous evidence which proves beyond all shadow of doubt that minerals can move up a stem through the phloem. To test this specific point more definitely I have repeated my earlier experiments on transport into defoliated shoots when first one tissue, the phloem, and then the other, the xylem, is cut. By using paired sets of shoots over 2 to 5 day periods, data have been obtained demonstrating conclusively that minerals moved into the growing shoot in greater quantities when the xylem was cut than when the phloem was cut. This was indicated by measuring gains in nitrogen, total ash, K and Ca.

Although many will agree that movement of minerals into growing shoots may take place through the phloem, they would contend that these materials came from the leaves and are probably in combination with organic matter, or are carried with organic matter in a mass flow of materials moving unidirectionally through the phloem. They contend further that minerals moving from the roots to the leaves are carried entirely in the water stream through the xylem. In order to determine whether minerals could move through the phloem from the roots to the leaves, experiments were carried out in which the effects of cutting the xylem between the leaves and roots were compared with those of cutting the phloem. In three sets of such experiments it was found that there was a significant loss of nitrogen over a 3 day period from the leaves of stems with xylem cut, and no gain or loss in the ringed stems. The deficiency of water resulting from cutting the xylem was probably responsible for the premature abscission of these leaves preceded by nitrogen removal. A modification of the experiment using divided roots clearly indicated a gain in nitrogen when the xylem was cut and no gain when the phloem was cut. The data, however, were not adequate to demonstrate clear significance when treated statistically.

It has been demonstrated that minerals moving out of leaves before abscission are carried via the phloem. There is strong evidence that materials in the phloem move along a concentration gradient. Palmquist in unpublished work has demonstrated movement of carbohydate and fluorescein to take place simultaneously in opposite directions through the phloem. Moose in unpublished work has demonstrated by spectroscopic and ordinary chemical analyses that the phloem

exudate of several tree species is rich in Ca, Mg, K, nitrate and total nitrogen and that the concentrations of these constituents often exceed the concentrations found in sap pressed from frozen leaves. Experiments here reported have demonstrated that nitrogen and minerals move to growing shoots more readily through the phloem than through the xylem. They also give strong but not entirely conclusive evidence that minerals moving from the roots to the leaves are carried in the phloem. Therefore the available evidence strongly supports the conclusion that under natural conditions the phloem of woody plants is the tissue chiefly concerned in transport from one part to another of nitrogen and minerals as well as sugars.

The Irrigation of Pears on a Clay Adobe Soil

By A. H. HENDRICKSON and F. J. VEIHMAYER, *University of California, Davis, Calif.*

EXPERIMENTS on the irrigation of pears were carried on in 1935 and 1936 at Kelseyville, Lake County, California. The trees used were of the Bartlett variety on French pear root-stock and were approximately 30 years old. All cultural operations were typical of those generally used in the community and were carried on by the owner. The practice for a number of years has been to grow a leguminous cover crop during the winter and to work it down in the spring. No fertilizers were applied to the experimental plots. The soil, classified in the Soil Survey as a Dublin Clay Adobe, contains about 50 per cent clay and exhibits typical adobe structure. The moisture equivalent varies from 25.5 to 27.3 per cent in the top 4 feet of soil. The experimental plots were small, consisting of four trees each surrounded by suitable guards. No attempt was made to secure accurate yield records. The data obtained were on the soil-moisture conditions during the growing season, and on the growth and keeping qualities of the fruit.

The soil-moisture conditions were found by sampling in one foot increments, at four places in each plot, by means of a soil tube at bi-weekly intervals. The record for the 1935 season which is similar to that of 1936 is given in Fig. 1. The wet plot, treatment A, was irrigated on June 27 and on July 24, or shortly after the regular sampling dates in the latter parts of June and July. The dry plot, treatment B, received no irrigation water during the time the fruit was on the trees. The soil-moisture record shows that the permanent wilting percentage was reached in the top 4 feet about July 9 as indicated by the flattening of the moisture extraction curves. The records for the fifth and sixth feet show some use of water throughout the period between the last of April and the middle of August. Because of the topography of the region in which this orchard is located, standing water was encountered at a depth of 4 feet during the winter and early spring. Later in the year the water table slowly receded and the trees were able to reduce the moisture in the fifth and sixth foot depths to a certain extent. While the trees apparently obtained some water from these depths, the amount obtained was evidently not sufficient to keep the fruit growing at the normal rate when the readily available moisture in the top 4 feet was exhausted.

The growth of fruit is shown in Fig. 2. The average increases in circumferences of the fruits from both plots were approximately equal between May 14 and June 25. Examination of the soil-moisture curves in Fig. 1 shows that both plots had readily available moisture during this period. On July 9, the fruit from the dry plot, which up to that time had been slightly larger, was found to be slightly smaller than that from the wet plot. Thereafter, the fruit in the dry plot grew more slowly than that in the wet. The decreased growth in the dry plot occurred about the time that the moisture content in the top 4 feet reached the permanent wilting percentage.

It is apparent from Fig. 2 that the curves of the circumferences of pears in both A and B treatments are substantially linear with respect to time, between May 14 and June 25. If volumes of the fruits instead of circumferences were plotted against time, the growth curve is concave upward with respect to the time axis, until July 9 when the soil-moisture content was reduced to about the permanent wilting percentage in the top 4 feet of soil in treatment B. Furthermore, if rates of increase in volume of fruit for the B treatment, for the period between May 14 and July 9 were plotted, it will be found that there is an increase in the rate of growth even though the soil-moisture content during this period is slowly decreasing. These results are in accordance with the data obtained in other irrigation experiments with pears on soils of coarser texture than the one used in this experiment. Similar results were obtained in 1936 except that it was not possible to subject the trees in treatment B to as severe conditions of soil moisture as in 1935. Late rains and cloudy weather in June decreased the loss of soil-moisture and the readily available moisture was not exhausted from the top 4 feet of soil in the dry plot until a few days before picking.

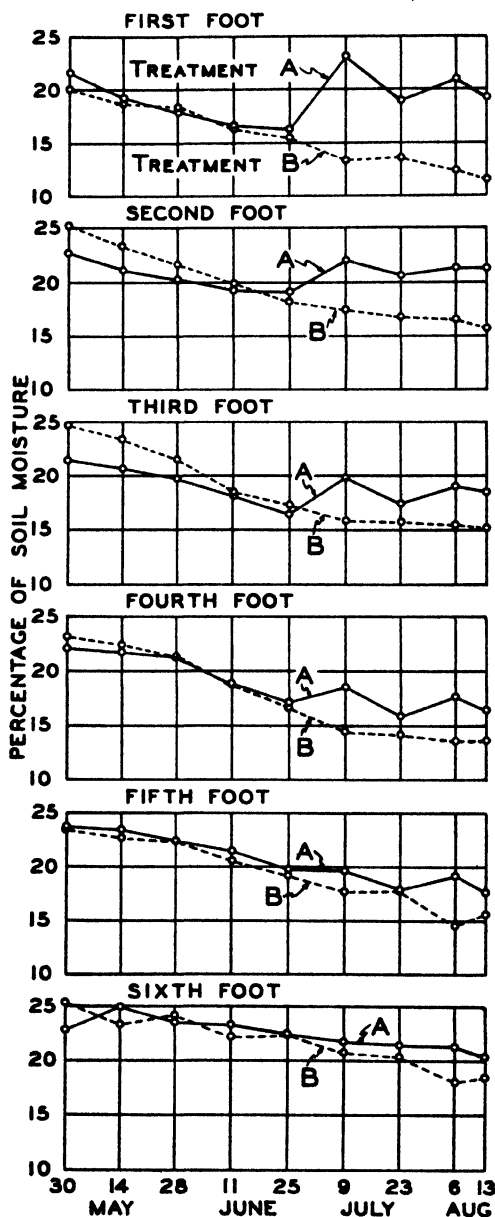


FIG. 1. Soil-moisture conditions in Bartlett pear orchard, Kelseyville, in 1935.

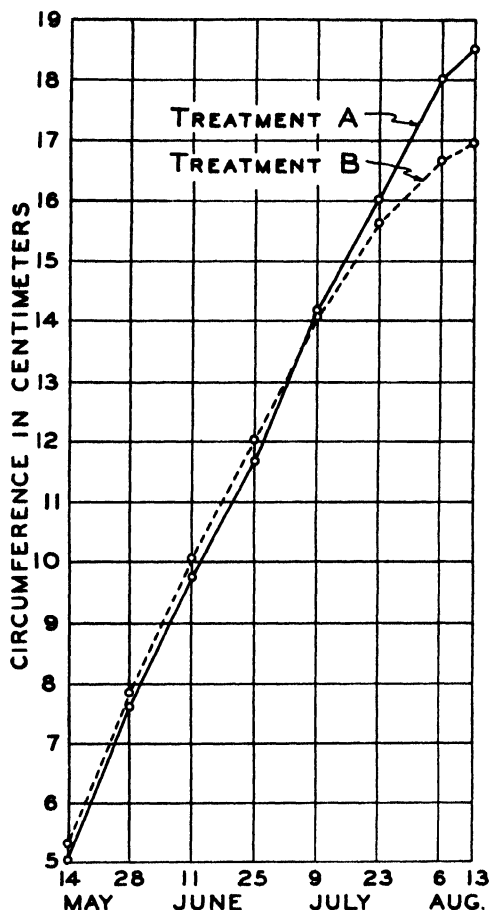


FIG. 2. Circumferences of Bartlett pears at Kelseyville in 1935.

The first picking was made on August 8 and the second on August 13. Fruit from both plots was taken to Davis where it was divided into two lots, one of which was stored at 36 degrees F and the other at 50 degrees F. After 2 weeks in storage the fruit was removed and kept at room temperature (about 70 degrees F). Notes were kept on changes in color and representative samples were tested at 2-day intervals with a pressure tester using a 5/16-inch plunger. No essential differences in keeping quality were found either year.

The data presented substantiate, in general, results that we have obtained with several other fruits. They show that keeping quality of Bartlett pears as measured by storage tests was not affected even when the fruit was subjected to the relatively severe conditions described in this paper. The growth of the fruit was decreased at approxi-

mately the time when the soil moisture was reduced to the permanent wilting percentage in the top 4 feet. No evidence was obtained to show that a decrease in growth of fruit occurred before the permanent wilting percentage was reached.

Relative Efficiency of Spur and Shoot Leaves for Fruit Growth of Pears¹

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Medford, Ore.*

STUDIES of pear pruning have shown that, with equal leaf area per fruit, heavier dormant pruning has resulted in larger fruits. Investigation of the possible factors involved has shown that heavier pruning increased the total length of new shoot growth and the proportion of shoot leaves in the total leaf area per tree. This suggested the need for the comparison of spur and shoot leaves in relation to fruit growth.

METHODS

Determinations were made of volume increase of tagged fruits on ringed limbs with only spur or shoot leaves, and with approximately the same leaf area per fruit for each type of leaves. A typical pair of Anjou limbs at the end of the 1936 season is shown in Fig. 1. The total leaf area on each limb was obtained by multiplying the total number of leaves by the estimated area per leaf. This estimate was made by comparing 150 to 200 leaves with leaf-shaped patterns of known area and recording the pattern areas that most nearly equalled those of the leaves. For each type of leaf 10 limbs were used. In 1933, 1934 and 1935 the trees were sufficiently alike to average the volume increase for all fruits on limbs with one type of leaf, regardless of the number of trees used. The probable error of such an average volume increase was then determined by Bessel's formula:

$$\text{P.E.} = \frac{\pm .6745 \sqrt{\frac{D^2}{n}}}{\sqrt{n-1}}$$

In 1936 available trees were more variable, so limbs were paired and one limb in each pair was used for each type of leaf. In this case the difference in average fruit volume increase for shoot as compared with spur leaves on each pair of limbs was determined, and the statistical significance of the average of the fruit growth differences for all pairs of limbs was determined by Student's method. All trees were in clay adobe soil and showed, as judged by reduced fruit growth, small water deficiencies during periods of high evaporating power of the air. All were probably well supplied with nitrogen, except two sets of Anjou trees used in 1936.

Since Haller and Magness (3) found that apple fruits secured food materials with equal facility from leaves up to a distance of 135 cms., it was assumed that having all pear fruits within 100 cms. of at least 400 sq. cm. of leaf area would give all fruits an equal supply of food from the leaves. Whitehouse (4) and also Haller and Magness (3)

¹This is a report of a cooperative project between the U. S. Department of Agriculture and the Oregon Agricultural Experiment Station.

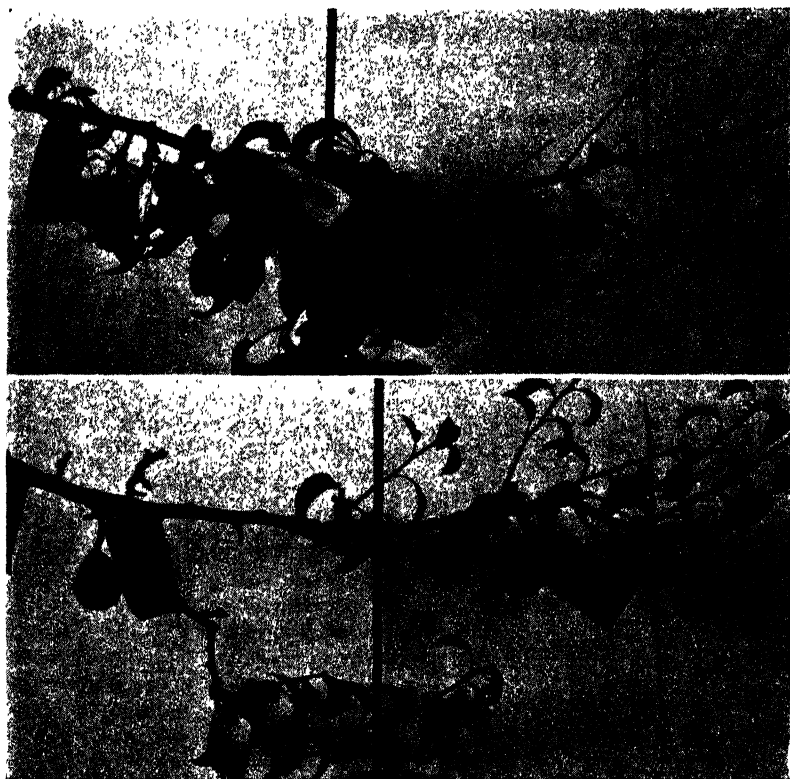


FIG. 1. Ringed Anjou limbs in late August, showing type of limb used for comparing efficiency of shoot and spur leaves. A, Ringed Anjou limb with 400 sq. cm. of leaf area per fruit = Spur leaves only. B, Ringed Anjou limb with 400 sq. cm. of leaf area per fruit = Shoot leaves only.

found that the size of apples at the beginning of the season is positively correlated with their size at the end of the season. Therefore only fruits having about the same average initial volume were used for measurement from limbs with each type of leaves. When fruits were knocked off, sufficient leaves were removed within 6 days to make the leaf area per fruit the same as before.

FRUIT GROWTH PER UNIT AREA OF LEAVES

Since Haller and Magness (3) found that the larger differences in fruit growth for a given difference in leaf area occurred with the smaller leaf areas per fruit, it was thought that the lowest feasible leaf area per fruit would be most likely to show possible difference in leaf efficiency between spur and shoot leaves. However, the leaf area of 200 sq. cm. per fruit used in 1933 showed (Table I) no greater fruit enlargement for shoot than for spur leaves. These trees had received

only a light-to-medium pruning and the available shoot leaves were relatively small in size and on short shoot growths. Therefore in 1934 heavily pruned trees (Anjou B), as well as more lightly pruned trees (Anjou A) were used. In 1934, only the comparison on the heavily pruned trees (Anjou B) showed significantly greater fruit enlargement with shoot than with spur leaves.

TABLE I—COMPARISON OF SPUR AND SHOOT LEAVES IN RELATION TO AMOUNT OF FRUIT ENLARGEMENT PER UNIT OF AREA OF LEAVES

Variety	Type of Leaf	Average Area per Leaf (Sq cm)	Average Fruit Volume at Start (Cc)	Average Total Increase in Fruit Volume After Leaf Adjustment, with Probable Error of Average (Cc)	Percentage Greater Fruit Enlargement with Shoot Leaves (Per Cent)	Statistical Significance of Greater Fruit Enlargement with Shoot Leaves
<i>1933 (200 sq. cm. of Leaf Area per Fruit)</i>						
Anjou . .	Spur	17.8	49.7	40.8 ± .98		None
	Shoot	18.9	48.7	40.9 ± .89	0	0.1 ± 1.32
<i>1934 (500 sq. cm. of Leaf Area per Fruit)</i>						
Anjou A . .	Spur	17.1	79.9	86.2 ± 1.08		None
	Shoot	23.1	79.6	90.8 ± 1.36	5.3	4.6 ± 1.74
Anjou B . .	Spur	21.0	90.6	87.6 ± 2.05		Significant
	Shoot	26.0	90.2	102.5 ± 1.59	17.0	14.9 ± 2.59
<i>1935 (400 sq. cm. of Leaf Area per Fruit)</i>						
Anjou . . .	Spur	20.1	73.5	50.6 ± 1.35		Significant
	Shoot	25.3	73.4	65.0 ± .94	28.4	14.4 ± 1.71
Anjou .	Small*	12.2	66.7	38.0 ± 1.36		Significant
	Large*	26.4	66.9	46.9 ± .84	23.4	8.9 ± 1.60
<i>1936 (400 sq. cm. of Leaf Area per Fruit)</i>						
Anjou .	Spur	21.5	72.3	50.4		Significant
	Shoot	23.8	72.9	58.5	16.1	by odds 9999:1
Bosc	Spur	24.8	67.4	64.3		Significant
	Shoot	27.5	67.7	75.5	17.4	by odds 344:1
Bartlett . . .	Spur	19.6	90.3	43.7		Significant
	Shoot	20.2	86.9	49.7	13.7	by odds 416:1

*Spur leaves.

In 1935 the comparison was repeated again, using larger limbs higher in the tree, where shoots were longer than those on the limbs used in 1933 and 1934. In 1935 shoot leaves, which averaged 26 per cent larger than spur leaves, produced 28 per cent greater fruit enlargement per unit area than the spur leaves.

Since shoot leaves were generally found to be larger than spur leaves, the factor of leaf size was considered. Since large spur leaves, 116 per cent larger in area than small leaves, were found to produce (Table I) 25 per cent more fruit growth per unit area, it seemed probable that the factors which increased leaf size also increased the efficiency of a unit area. However, during the same year shoot leaves only 25 per cent larger than spur leaves, produced 28 per cent more fruit per unit area,

which seemed to indicate that the greater efficiency per unit area of shoot leaves was influenced not only by factors related to their larger size but also by other factors possibly related to their position on vigorous shoots rather than on spurs.

In 1936 the comparisons for each of three varieties again showed greater fruit enlargement with shoot than with spur leaves. Furthermore three additional comparisons on Anjou (data not given) showed shoot leaves to be 17.6, 12.3 and 28.4 per cent more efficient than spur leaves, with statistically significant odds in each case. Thus in eight out of ten comparisons of shoot with spur leaves, a given area of shoot leaves proved to be more efficient for fruit enlargement than a similar area of spur leaves.

CHARACTERISTICS OF SPUR AND OF SHOOT LEAVES

Dry weight determinations on leaf discs of known area show (see Table II) that the shoot leaves had a greater amount of dry matter per unit area than the spur leaves. This indicates that shoot leaves had either more layers of cells, or longer or more dense cells. Since Cowart (2) found the palisade layer of exposed apple leaves thicker for shoot leaves than for spur leaves, it seems probable that the observed differences in dry matter per unit area for these pear leaves may indicate a greater thickness of the palisade layer in shoot than in spur leaves.

TABLE II—COMPARISON OF SPUR AND SHOOT LEAVES IN RELATION TO DRY WEIGHT AND NITROGEN PER UNIT AREA OF LEAVES

Variety	Type of Leaf	Dry Matter in Leaves			Total Nitrogen in Leaves	
		Percentage of Fresh Weight	Milligrams per 400 Sq. cm. of Area	Percentage Greater Dry Matter Per Unit Area in Shoot Leaves	As Percentage of Dry Weight	As Milligrams per 400 Sq. cm. of Area
		(Per Cent)	(Mgm)	(Per Cent)	(Per Cent)	(Mgm)
1935						
Anjou ...	Spur	43.08	3.819	23.5	.839	32.0
	Shoot	43.42	4.715		.869	41.0
1936						
Anjou . . .	Spur	53.70	4.567	9.7	1.446	66.04
	Shoot	53.40	5.011		1.512	75.77
Bosc. . . .	Spur	50.20	4.621	6.5	2.277	105.22
	Shoot	50.59	4.921		2.322	114.26
Bartlett..	Spur	48.13	4.868	14.3	1.915	93.22
	Shoot	49.75	5.566		1.723	95.91

The shoot leaves were produced during the 5 to 7 weeks of shoot elongation, which did not begin until about 2 weeks after spur leaves were fairly well formed. Thus the shoot leaves were younger, and also developed during days when air temperature and light intensity were probably higher. If these factors were effective, the younger shoot leaves should have more dry matter per unit area than the older shoot leaves. Dry matter determinations for leaf discs of known area, obtained at the end of 1936, showed that the oldest and the youngest leaves on

spurs had 3.95 and 4.03 grams of dry matter (per 400 sq. cm. of leaf area), respectively, whereas leaves at the base, middle and end of the shoot had 4.73, 5.14 and 5.92 grams respectively. These data indicate that the greater efficiency of shoot than spur leaves may be related to conditions in the spring at the time the leaf is produced.

To obtain an approximate measure of the total amount of protoplasm in these leaves, the dry matter was analysed for alcohol insoluble and soluble nitrogen. Alcohol soluble nitrogen in these leaf samples, taken in late summer, was very low; and the alcohol insoluble nitrogen was proportional to and almost equal to the total nitrogen. Since the percentage of total nitrogen per dry weight of leaves (Table II) was slightly greater for shoot than for spur leaves of Anjou and Bosc, it would seem that the protoplasm of shoot leaves of these two varieties may have contained slightly greater concentrations of such substances as chlorophyll and protein than did spur leaves. However, with shoot leaves having a greater weight of dry matter per unit area than the spur leaves, the total nitrogen per unit area was much greater for the shoot leaves and the amount of nitrogenous substances in the protoplasm was probably also greater per unit area. The Bartlett variety, however, had a lower percentage of total nitrogen in the shoot than in the spur leaves, with the shoot leaves having about the same total nitrogen per unit area as the spur leaves.

To compare the efficiency of leaves more accurately, the increase in dry matter in Anjou fruits produced with spur and shoot leaves in 1936 was determined. Dry matter at the beginning was determined for fruits comparable to those on experimental limbs, and dry matter at the end was determined for the measured fruits on the ringed limbs.

The resulting calculations (Columns A and B in Table III) show that 400 sq. cm. area of Anjou shoot leaves produced from 24 to 49 per cent more fruit dry matter than spur leaves. This increased production of fruit dry matter by shoot leaves is of greater magnitude than the increased dry matter per unit area of the shoot leaves (Column C in Table III). To show this feature another way, increase in fruit dry matter per 400 sq. cm. of leaf area was divided by the dry matter of 400 sq. cm. of leaf area, the quotient being given in Column D. It is evident that a gram of dry matter of Anjou shoot leaves produced from 12 to 29 per cent more fruit dry matter than a gram of dry matter of spur leaves. Thus shoot leaves on these Anjou trees were apparently more active photosynthetically than the spur leaves. Of the four comparisons with Anjou in 1936, three had slightly more nitrogen as percentage of dry weight in the shoot than in the spur leaves, indicating that in these three comparisons slightly greater protoplasm in the shoot leaves might have been one contributing factor to their greater efficiency. Exposure to sunlight was very similar for each pair of limbs. Studies comparing the daily duration of stomatal opening for shoot and spur leaves on unringed limbs showed in some cases slightly longer opening in shoot leaves for short periods, but the differences were by no means as great as the differences in stomatal opening found by Aldrich and Work (1) in 1932 for adjacent Anjou trees, when increased availability of soil moisture resulted in about 25 per cent greater fruit enlargement.

TABLE III—COMPARISON OF SPUR WITH SHOOT LEAVES OF ANJOU IN RELATION TO AMOUNT OF DRY MATTER IN FRUIT PRODUCED BY A UNIT DRY MATTER IN LEAVES

Type of Leaf	Column A	Column B	Column C	Column D	Column E
	Calculated Increase in Dry Matter in Fruits Per 400 Sq. cm. of Leaf Area (Gm)	Percentage Greater Dry Matter Increase of Fruits with 400 Sq. cm. Area of Shoot than Spur Leaves (Per Cent)	Percentage Greater Dry Matter in 400 Sq. cm. Area of Shoot than Spur Leaves (Per Cent)	Calculated Increase in Dry Matter in Fruit Per Gram of Dry Matter in Leaves (Gms. per Gm)	Percentage Greater Efficiency for Fruit Dry Matter Increase for Unit Dry Matter in Shoot than in Spur Leaves (Per Cent)
Spur*	9.15	—	—	2.00	—
Shoot*	11.64	27	10	2.32	16
Spur	7.69	—	—	1.72	—
Shoot	10.35	35	12	2.08	21
Spur	8.33	—	—	1.89	—
Shoot	10.32	24	10	2.12	12
Spur	8.33	—	—	1.98	—
Shoot	12.38	49	15	2.56	29

*Comparison previously given in Table I for Anjou in 1936.

SUMMARY

On ringed pear limbs a unit area of shoot leaves resulted in significantly greater fruit enlargement than an equal area of spur leaves in eight out of ten experiments. In the other two cases the difference was not significant. Shoot leaves had more dry matter per unit area than spur leaves, and a gram of dry matter of shoot leaves seemed to produce from 12 to 29 per cent more fruit dry matter than did an equal amount of dry matter of spur leaves. No explanation was found for this apparently greater activity of shoot leaves.

The author is indebted to Dr. J. R. Magness for suggestions in preparation of this report.

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Fruit Bud Hardiness in Peach Varieties

By R. L. McMUNN, *University of Illinois, Urbana, Ill.*

IN this paper are presented data, taken over a 4 year period, on the fruit bud hardiness of 43 peach varieties which were growing in the peach variety orchard at Urbana, Illinois. When the counts were begun, it was hoped they could be carried on over a longer period; but due to the very severe injury and loss of trees following the winter of 1935-36, it has been necessary to remove the orchard.

The trees were planted in the fall of 1926, except Hiley in 1927 and Gage in 1928, and produced the first crop in 1931. The soil cultural treatments have been the same each year, namely two discings, one given fairly early in the spring, the other in early summer. Native vegetation, (mostly crabgrass) has been allowed to grow in place of a fall seeded cover crop. Pruning has been uniform on all varieties in a given year, but varied in severity from year to year, depending on whether there was a crop or no crop. In 1931, light thinning was done on selected limbs of Lemon Free, Martha, October Elberta, and Wilma. However, the amount of fruit removed probably was not enough to have any influence on bud hardiness during the winter of 1931-32. Other than this thinning, none was done on the trees from which the bud killing records were secured. In 1935 part of the blossoms of Buttercup, Greenshoro, Heath Cling, Marigold, and June Elberta, were hand pollinated, the non-pollinated blossoms being pulled off. This materially reduced the yield, therefore the yield for these are not recorded in Table I for that year. Records on Golden Sweet and Hale were discontinued in 1935 because the trees appeared non-vigorous. No commercial fertilizers have been used during the period. Due to the few insects and absence of brown rot, spraying and dusting has been light, none being applied in the no-crop years. Since all the cultural treatments on the record trees were the same excepting light thinning on four varieties in 1931, any bud killing can therefore be attributed to varietal differences in hardiness or due to over-cropping.

MATERIAL

Terminal shoots which represented the average length for the variety were secured from a height of 3 to 6 feet from the ground. Shoots of a variety were from a single tree and the collections each year were from the same tree, thus the bud killing over the 4 years represents the performance of a single tree of the variety. Two hundred or more buds were examined on each variety when collections were made, except in 1933 on Early Elberta, Hale, Meteor, Rochester, Sea Eagle, and South Haven, a year when these varieties had an exceptionally light bud set. All shoots, after being cut, were kept in a cold storage room at 32 to 38 degrees F for 24 to 48 hours before counts were made.

WINTER TEMPERATURES WHEN KILLING OCCURRED

A brief summary of the winter temperatures when bud killing occurred are as follows:

1931-32.—The winter of 1931-32 was very mild, with monthly minima of 21 degrees F November 28; 22 degrees F December 2; 7 degrees F January 30; and 12 degrees F on February 1. Each of the above minima were preceded and followed by relative high temperatures with no rapid fluctuations. On March 5, counts were made; these are shown in Table I, column 1. The greatest kill, however, occurred from March 6 to 10 at minima of 6 degrees F on the 6th, followed by 5 degrees F, 8 degrees F, 5 degrees F, and 6 degrees F on the 10th. At the time of this cold period, the buds were considered about 10 days further advanced than normal. The counts following this period are shown in column 2. The kill shown in this column is the total kill for the winter and not the kill which occurred from March 6 to 10.

1932-33.—Although the buds were subjected to a moderately low temperature rather early (8 degrees F November 20), only an occasional dead bud could be found on December 1. The killing for 1933 shown in column 3 occurred from December 12 to 18 when minima of 2 degrees F on the 12th followed by 1 degree F, 7 degrees F, -3 degrees F, -9 degrees F, 3 degrees F, and 2 degrees F, on the 18th were recorded. Probably most of the killing and with some varieties all of the killing occurred when the -9 degrees F was recorded. No further killing was found following -2 degrees F on February 5. Minima of -7 degrees F on February 8, and -13 degrees F on the 9th, killed the remaining live buds.

1933-34.—No dead buds were found after a -2 degrees F reading on December 27, a -2 degrees F on January 29, and -1 degree F on January 30. On February 9 a minimum of -2 degrees F was recorded. This was preceded by a maximum of 44 degrees F 24 hours earlier. The killing for 1934 shown in column 4 occurred at this time. Unfortunately collections could not be started until February 26 and before shoots of all the varieties could be gotten a minimum of -10 degrees F on the night of February 26 killed practically all the buds. An occasional live bud could be found on Buttercup, Marigold, Massasoit, Meteor, Oriole, Radiance, and Greensboro. Greensboro, the most resistant of these varieties, had fewer than 1 per cent live buds.

1934-35.—The killing for 1935 shown in column 5 occurred during the period January 22 to 24 at temperatures of 2 degrees F, 1 degree F, and -3 degrees F. Previous to that time, minima of 0 degree F on December 26 and -1 degrees F on the 27th, resulted in no killing. No killing occurred after January 24.

1935-36.—The buds were killed early in the winter at temperatures of -5 degrees F on December 25, followed by -5 degrees F on the 26th and -9 degrees F on the 27th. Later in the year the long sub-zero period killed or severely injured most of the trees in the orchard.

RESULTS

The data on the percentages of bud killing and the yield in pounds for the 1932 and 1935 crops are shown in Table I. A survey of these data along with the weather records noted above, disclose the following in regard to killing at different temperatures. In 1931-32 some killing occurred at a temperature no lower than 7 degrees F during the winter,

TABLE I—SHOWING THE PERCENTAGE OF BUD KILLING, THE YIELD IN POUNDS AND THE CLASS RANKING FOR FORTY-THREE PEACH VARIETIES

Variety	Percentage Bud Kill					Class Ranking				Yield (Pounds)	
	1932		1933	1934	1935	1932	1933	1934	1935	1932	1935
	(a)	(b)									
Alton.....	10	22	12	—	16	2	1	—	1	95	184
Belle.....	11	30	8	23	29	2	1	2	2	117	230
Brackett.....	3	55	48	—	48	3	4	—	2	Few	54
Buttercup.....	4	16	6	13	38	1	1	1	2	22	—
Captain Ede.....	0	24	19	—	37	2	2	—	2	38	100
Carman.....	3	17	4	—	23	1	1	—	1	84	221
Chairs.....	1	50	28	—	54	3	2	—	3	59	154
Champion.....	8	24	31	28	62	2	2	2	3	347	209
Delicious.....	0	82	8	—	32	4	1	—	2	4	232
Early Elberta.....	6	22	12	—	31	2	1	—	2	116	132
Elberta.....	2	55	25	48	41	3	2	4	2	—	—
Gage.....	6	36	—	35	40	2	—	3	2	—	—
Gold Drop.....	4	28	9	20	11	2	1	1	1	181	154
Golden Sweet.....	2	24	26	—	—	2	2	—	—	160	96
Greensboro.....	3	3	5	13	13	1	1	1	1	171	—
Hale.....	9	32	28	55	—	2	2	4	—	13	—
Heath Cling.....	11	36	17	29	42	2	1	2	2	48	—
Hiley.....	1	22	10	—	57	2	1	—	3	44	138
Japan Giant.....	1	39	4	—	23	2	1	—	1	70	54
June Elberta.....	4	18	5	—	15	1	1	—	1	23	—
Kalamazoo.....	11	33	13	32	6	2	1	2	1	152	122
Krummel.....	4	65	12	—	20	4	1	—	1	34	60
Late Elberta 10*.....	0	14	6	—	—	1	1	—	—	141	—
Late Elberta 16*.....	3	42	16	—	53	3	1	—	3	130	78
Lemon Free.....	11	52	15	24	38	3	1	2	2	52	116
Marigold.....	3	8	5	18	7	1	1	1	1	221	—
Martha.....	5	71	59	—	50	4	4	—	3	166	216
Massasoit.....	3	9	6	14	23	1	1	1	1	208	156
Metcor.....	5	6	2	39	11	1	1	3	1	135	126
Oct. Elberta.....	1	72	35	—	41	4	3	—	2	40	102
Oriole.....	4	42	6	15	38	3	1	1	2	215	245
Pioneer.....	5	15	2	21	34	1	1	1	2	119	89
Primrose.....	10	82	16	34	88	4	1	2	4	24	144
Radiance.....	4	72	5	35	52	4	1	3	3	199	154
Rochester.....	4	8	16	19	16	1	1	1	1	238	159
Rosebud.....	8	16	6	18	12	1	1	1	1	200	183
Salwey.....	1	64	11	31	36	4	1	2	2	70	42
Sea Eagle.....	4	56	18	—	40	3	1	—	2	341	196
Smock.....	6	19	12	—	46	1	1	—	2	68	48
South Haven.....	2	23	18	27	56	2	1	2	3	112	212
Sunbeam.....	13	21	5	42	68	1	1	3	3	72	194
Wilma (late form).....	5	55	36	—	45	3	3	—	2	59	192
Yellow St. John.....	12	76	35	52	69	4	3	4	3	35	50

*From different nurseries.

(a) Before March 5.

(b) After cold period of March 6 to 10.

while later in the year medium to severe killing occurred at 5 to 8 degrees F. In 1932-33 a minimum of -9 degrees F killed fewer buds than in the previous year when the temperature was considerably higher. Later in the year -13 degrees F killed all the buds. On two different days in 1933-34 a temperature of -2 degrees F caused no

killing; but on a third occasion with a rapid drop in temperature to -2 degrees F, a greater kill resulted than in the previous year at -9 degrees F. Also later in 1933-34 practically a complete kill occurred at -10 degrees F, while in the previous year at -9 degrees F decidedly fewer buds were killed. The kill in 1934-35 was higher with most varieties than in 1932-33 even though the minimum temperature was 6 degrees higher in 1935. For the 1936 crop -9 degrees F killed all the buds, yet in 1932-33 at this same temperature there was only a light to medium kill. These data bear out the reports of investigations and observations of growers relative to the fact that peach fruit buds withstand different degrees of cold, depending on the advancement of the bud, time of year when the cold occurs, rapidity of temperature drop or rise, and duration of the cold.

The data in columns 1 to 5 show clearly a marked difference in the resistance of the fruit buds of the different varieties to the same degree of cold. The greatest variation in kill between the varieties took place when the killing occurred late in the winter at the highest killing temperature recorded during the 4-year period, (March 6 to 10, 1932). The range that year after March 10 was from 3 per cent for Greensboro to 82 per cent with Delicious and Primrose. In this connection it is interesting to note, that some of the varieties showing the least kill before March 6, had the greatest kill after the March 6 to 10 cold period. This is similar to the observations reported by Blake (1).

A survey of the data on the percentage of kill also show that varieties do not hold the same relative rank, one to another, year after year. This is brought out more clearly if the varieties are grouped in classes as has been done in columns 6 to 9 in Table I. In this classification those varieties falling in the lower most fourth in killing (most hardy) are placed in Class I, those in the second fourth in Class II, those in the third fourth Class III, and those in the upper fourth, (most tender) Class IV. In checking over the data in these columns for the varieties on which 4 years records were secured, it is seen that only Greensboro, Marigold, Massasoit, Rochester, and Rosebud have fallen in the same class during 4 years. These five varieties fell in Class I each year. Three years' records place Carman and June Elberta in Class I. Each of these seven varieties ripen with or before Carman. Of the remaining 36 varieties, only Captain Ede has fallen in the same class each year (Class II), and with this variety but 3 years' records were secured. Only three varieties, namely Martha, Primrose, and Yellow St. John, have been in Class IV during 2 of the 4 years. In this connection, it is of interest to note that Primrose was in Class I in 1933 and in Class II in 1934. Other varieties shifting from Class IV to Class I were Delicious, Krummel, Radiance, and Salwey. Brackett, Elberta, Hale, and October Elberta shifted from Class IV to Class II. Most of these 11 varieties ripen their fruit in mid-season or later.

Variations in hardiness ranging from Class I to Class II or III and from Class II to Class III are frequent.

Growers often classify varieties as hardy or tender, depending upon the yield of fruit. Shoemaker (2), also makes the same classification. It will be interesting then, to compare the yield secured from the trees

from which bud killing records were taken to determine if this is an accurate method of expressing the bud hardness of varieties. By comparing the yields in the crop years 1932 (Column 10) and 1935, (Column 11) with the bud killing for the same years (Columns 2 and 5) it is apparent that this is not an accurate method of expressing bud hardness. For example, in 1932 Brackett had a bud kill of 55 per cent and produced but a few fruits, while in 1935 with a 48 per cent kill it produced 54 pounds. Belle in 1932 produced 117 pounds with a 30 per cent kill and in 1935 230 pounds were harvested, with a 29 per cent kill. Comparing different varieties in 1932 on the basis of bud kill and yield the following may be noted: Greensboro 3 per cent kill, yield 171 pounds; Marigold 8 per cent kill, yield 221 pounds; Captain Ede 24 per cent kill, yield 38 pounds; Champion 24 per cent kill, yield 347 pounds. The differences occurred even though the trees had the same type and degree of pruning and were of approximately the same size. Such inconsistencies are to be found with most of the varieties. Such differences can be expected, due to the great variation to be found in the number of buds developed by the different varieties (3) and the variation in the bud level on the same variety from year to year (4). Greensboro and Brackett furnishes good examples of this point. Brackett is the shyest bud producer in the variety orchard and even though relatively few of the buds are killed and all of the fruit sets, a very small crop would be realized. On the other hand, with a variety like Greensboro which produces buds abundantly, a large kill would not necessarily give a small yield in bushels. Set of fruit, insects and diseases would also have an influence on yield.

The data shows the advisability of collecting data over a 3 or 4 year period from the same tree or trees to secure the approximate rating of a variety relative to its hardness, in relation to other varieties.

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Experiments on the Hardiness of Peach and Apple Fruit Buds (A Preliminary Report¹)

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IT has been shown (1) that as a peach tree enters the dormant season its buds become progressively more resistant to low temperatures. This is also shown in experiments conducted at the West Virginia Experiment Station in the fall of 1935 with four varieties (Table I).

TABLE I—THE WINTER HARDENING OF PEACH BUDS (1935-36)

Experiment Number	Variety	Lowest Temperature C. (Degrees F)	Buds Alive	Buds Dead	Per Cent Alive
<i>October 23, 1935</i>					
1	Elberta	16	193	100	65.8
1	Greensboro	16	433	388	52.7
1	Rochester	16	182	106	63.2
1	South Haven	16	171	83	67.3
<i>November 22, 1935</i>					
2	Elberta	16	278	32	90
2	Greensboro	16	250	17	93.6
2	Rochester	16	297	31	90.5
2	South Haven	16	200	36	85
<i>December 23, 1935</i>					
3	Elberta	9		No killing	
3	Greensboro	9		No killing	
3	Rochester	9		No killing	
	South Haven	9		No killing	
<i>December 25, 1935</i>					
4	Elberta	5	163	71	69.6
4	Greensboro	5	213	42	83.5
4	Rochester	5	63	103	38
4	South Haven	5	136	106	56.2
<i>January 20, 1936</i>					
5	Elberta	—8	201	79	71.7
5	Greensboro	—8	263	94	73.6
5	Rochester	—8	141	118	54.4
5	South Haven	—8	163	160	50.4

Rate of temperature drop² was approximately the same in all tests, particularly when near the lethal temperature. Exposure to lowest temperature was generally for about 1 hour. Varietal differences in hardiness may be less pronounced (1) in early winter than after the rest is broken. This also is shown by Table I. Elberta and Greensboro seem more hardy up to the end of this experiment. It could not be

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²A special General Electric freezing unit with Bristol temperature control was used in these experiments.

continued until spring because of low temperatures on January 23 which killed fruit buds of all varieties.

It has been shown by the author (2) that apical buds are the first, as measured by microspore development, to break rest in January followed by median and basal buds in order. After the rest has been broken they are likely to be started into growth by warm spells of weather. Thus, unfavorable temperatures in January and February usually injure apical and median buds more than basal ones. This apparently holds true in early winter also, at a time when buds are still in the rest. (Table II.) The greater tenderness of apical and median buds at this time, however, is probably due to immaturity. Thus one can conclude that at all times during the dormant season basal buds are in the main most hardy.

TABLE II—EFFECT OF BUD POSITION ON HARDINESS (1935-36)
(FOUR VARIETIES)

Date	Minimum Temperature (Degrees F)	Per Cent Alive		
		Basal Buds	Median Buds	Apical Buds
November 22	16	86.2	77.5	56.5
December 25.	5	72.4	48.0	61.2
January 20.	-8	65.3	58.4	56.9

When peach buds are coming out of the rest in late winter, a warm spell may start them into growth and make them more susceptible to low temperatures. On January 14, 1935 buds of several varieties of peach were subjected to a minimum temperature of -5 degrees F. Twenty per cent of Rochester were killed and 50 per cent of Belle. A short period of warm weather followed with temperatures as high as 50 to 60 degrees F. The experiment was repeated exactly on January 21 with the result that 60 per cent of Rochester buds were killed and 90 per cent of Belle.

It has been assumed that when buds are in the rest they are less likely to be influenced by warm spells with consequent growth and greater injury from low temperatures. To determine if this were true, branches of Champion and Carman were brought in November 29, 1935. One half the branches of each variety was placed in a cold storage (32 to 34 degrees F) and the other half at room temperature (70 to 75 degrees F). After 3 days all branches were subjected to a temperature of 0 degrees F. The Carman buds which had been at room temperature were all killed, while those which had been at cold storage temperature were 60 per cent killed. Champion buds at room temperature were 98 per cent killed, while those which had been in cold storage were 72 per cent killed. Thus peach buds in the rest period may also become more physiologically active and more tender when subjected to favorable growing temperatures.

How low a temperature can peach buds stand? Greensboro and Belle of Georgia buds were chosen for the test. Rate of fall was made very slow, a week being necessary to reach a minimum of -25 degrees F. As each successively lower temperature was reached sample

branches were removed, half being kept at room temperature and half in cold storage. Results are shown in Table III. All Belle of Georgia buds were killed by a -10 to -14 degrees F and Greensboro buds by a -14 to $-17\frac{1}{2}$ degrees F. Injury was not consistently influenced by rate of rise of temperature.

TABLE III—LETHAL TEMPERATURES OF GREENSBORO AND CARMAN BUDS
JANUARY 10, 1936

Variety	Sample	Temperature (Degrees F)	Buds Alive	Buds Dead	Per Cent Alive	Type Recovery (Degrees F)
Belle Greensboro	Check Check	— —	83 —	2 —	97.6 100.0	— —
Belle Greensboro	A A	0 0	68 31	4 6	94.4 83.8	32-36 32-36
Belle Greensboro	B B	-5 -5	11 65	2 8	92.3 89	32-36 32-36
Belle Belle Greensboro Greensboro	C C' C C'	-10 -10 -10 -10	22 51 43 39	9 14 6 1	71 78.5 87.7 97.5	32-36 70-75 32-36 70-75
Belle Belle Greensboro Greensboro	D D' D D'	-14 -14 -14 -14	0 0 21 30	55 55 7 57	0 0 75 34.5	32-36 70-75 32-36 70-75
Belle Belle Greensboro Greensboro	E E' E E'	$-17\frac{1}{2}$ $-17\frac{1}{2}$ $-17\frac{1}{2}$ $-17\frac{1}{2}$	0 0 0 0	71 53 59 60	0 0 0 0	32-36 70-75 32-36 70-75
Belle Greensboro	F F	-20 -20	0 0	31 47	0 0	32-36 32-36
Belle Greensboro	G G	-25 -25	0 0	61 127	0 0	Slowly back to room temperature

Rate of temperature fall may often be as important as the absolute temperature that obtains. In repeating an experiment it was always necessary to duplicate the rate of fall exactly in order to get comparable results.

When peach buds were killed on January 23, 1936, experiments were continued on apple buds. As shown in a previous paper (3), pith and conducting tissue at base of fruit buds are more tender than the individual flowers of the fruit bud. In contrast to peach buds where injury is always very definite, resulting in death, there may be all degrees of injury to apple flowers from slight to marked browning of pistil and anthers. As a result the observer often cannot determine whether or not injury has been fatal.

On February 21, 1936, buds of Grimes, Jonathan, McIntosh, Delicious, and Stayman were subjected to a temperature of -30 degrees F. Conducting tissue and pith below the fruit bud were badly browned in all varieties probably beyond recovery. McIntosh showed least injury

to the flowers and Grimes most. The center flower of the cluster always appeared most injured. Some flowers appeared alive in all varieties — most in McIntosh.

On February 26, 1936, fruit buds of Golden Delicious, Delicious, Rome and Transparent were subjected to a temperature of $-32\frac{1}{2}$ degrees F. Transparent fruit buds came through best with Rome next. Others were injured beyond recovery. In this experiment an idea of the rate of temperature fall may be gotten from the following: Buds were brought in to chamber at $+17$ degrees F. In 2 hours temperature was dropped to $+8$ degrees F. They remained at this temperature for 15 hours. Temperature was then dropped to $+30$ degrees F, where it remained for 24 hours. From this point it slowly went down to $-32\frac{1}{2}$ degrees F. Twelve hours were required for this last drop. Temperature was then allowed to return slowly to room temperature by cutting off refrigeration. Usually about 24 hours' time was required for this.

Rate of temperature rise after a killing frost near bloom time is considered to have little effect on the severity of injury. On April 16 when flowers were in the prepink stage some Delicious flowers were subjected to a temperature of 16 to 18 degrees F. Half of them were immediately taken out and placed in water at room temperature, the other half placed at 32 degrees F and the temperature gradually brought back to room temperature. Pistil killing was the same in both lots although distinctly less wilting of flower clusters and less anther injury in the lot brought gradually to room temperature.

CONCLUSION

1. Peach buds harden off rapidly in late fall and early winter. Varietal differences in hardiness are less pronounced at this time than after the rest has been broken. Basal buds are more hardy in late fall and early winter than are apical and median buds. Buds of Champion and Carman peaches can be made more tender when in the rest in late November, by subjecting them to temperature of 70 to 75 degrees F. Belle of Georgia buds stood temperatures of -10 degrees F or more and Greensboro buds -14 degrees F or more, experimentally. Rate of temperature rise did not seem to affect injury.

Transparent, McIntosh, and Rome buds were more hardy in February than Grimes, Delicious, Golden Delicious, and Stayman buds. A few of the former withstand a temperature of $-32\frac{1}{2}$ degrees F under the conditions of the experiment. At this temperature there was severe conducting and pith tissue injury. When subjected to low temperatures, Delicious buds in the prepink stage showed less wilting and less anther injury when the rate of temperature rise was slow.

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Some Effects of Four Years of Cover Crops in a Young Peach Orchard

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MOST peach orchards in the eastern United States are planted on the higher elevations to obtain good air drainage. On these locations, the soil is often shallow and under frequent cultivation is quite subject to erosion, consequently in recent years there has been considerable interest in the use of cover crops as well as the possible use of sod to supplement clean tillage in the peach orchard.

In the spring of 1932 an investigation was started to determine the effects of various covers on the growth and fruitfulness of peach trees. Approximately 600 Elberta trees were planted on an upland soil, classified as sassafras gravelly loam, and an equal number of Belle trees was planted on a sandy loam soil at the United States Horticultural Field Station, Beltsville, Maryland. While duplicate plot treatments were laid out on both soil types, only the results obtained in the Elberta orchard will be considered here.

The trees were given uniform cultural treatment during the first year after planting, consisting of a summer cover of soybeans that was turned under in August, followed by a winter cover of rye and vetch, turned under the following April. The trees made uniformly good growth.

The plot treatments laid out early in the spring of 1933, consisted of clean cultivation in the spring followed by summer covers of soybeans, buckwheat, and crotalaria, legume sods of Korean lespedeza, *Lespedeza sericea*, and biennial sweet clover; and summer cultivated plots, some of which received an annual application of approximately 5 tons of manure. Each plot consisted of a single record row of 21 trees, with the adjacent rows serving as buffers. Thus the centers between the record trees and buffers were all occupied with cover crops except for a cultivated strip that was left on either side of each tree row, and which was extended in width as the trees grew older. All plots, with the exception of crotalaria, were replicated once. The summer covers were seeded about June 1 and disced about August 15 to September 1, when a winter cover of rye and vetch was seeded on all cultivated plots. This was turned under in the spring when the rye was about knee high. The lespedeza plots were disced up once in early spring to incorporate the dried plant residue into the soil and to permit reseeding. Two biennial crops of sweet clover grown during the period of the experiment were disced under following seed formation in each second year. The first was not clipped before turning under, but the second crop was clipped in the first and second years.

The soil over all plot areas was uniformly limed before the plots were established. All summer cover crop plots received an application of 5-8-5 fertilizer drilled in with the seed and a similar amount with the fall seeding of rye and vetch. The legume sods received the same fertilizer in a single spring application, which was increased to 350

pounds in the fourth year. In addition to these cover crop applications, nitrate of soda was broadcast under the trees at the rate of $\frac{1}{2}$ pound per tree and doubled in amount annually up to 3 pounds on 3- and 4-year-old trees.

An excellent plant growth was obtained on all of the cover crop plots, including the winter cover of rye and vetch, excepting crotalaria, in which weeds predominated in two of the years.

Soil samples were taken at the beginning of and during the experiment for organic matter content and acidity, and at weekly intervals during periods of dry weather for moisture determinations. Records have been taken on soil nitrates, amount of cover crop produced, and tree behavior and fruit production.

RESULTS

Tree Growth:—The trees on all plots at the start of the experiment were quite uniform, although plots 5 and 7 averaged slightly smaller than the rest. (Table I.) At the end of the first year of differential

TABLE I—AVERAGE CIRCUMFERENCE GROWTH OF ELBERTA PEACH TREES, 1932 TO 1936, AND YIELD OF FRUIT, 1936

Plot	Treatment	Year 1932 (Cms)	Year 1936 (Cms)	Gain (Cms)	Yield per Tree (Pounds) 1936	Number Peaches per Tree, 1936
5	Manure	6.0	35.3	29.36±.489	151.3	678
7	Cultivation	6.4	32.0	25.61±.543	58.1	288
9	Lespedeza	6.5	25.6	19.12±.353	21.2	120
11	Sweet clover	6.6	24.3	17.68±.490	21.1	127
13	Soybeans	6.8	28.9	22.07±.393	47.2	242
15	Buckwheat	6.7	27.6	20.97±.388	44.9	245
17	Cultivation	6.9	31.4	24.48±.328	48.0	246
21	Crotalaria	6.8	28.0	21.21±.584	48.5	257

cover crop treatment, differences in tree growth between plots was noticeable, although strip cultivation had been given along the tree rows. In the second and third years the differences in tree growth were more marked and distinct differences in tree size could be noted, particularly between no summer cover plots and the legume sods. When average terminal growth of a given number of branches was compared during this period the differences in length were not so marked, but there was a great difference in the total number of terminals, laterals, and main branches. Growth habit was noticeably modified on the sweet clover plots, where the main branches with few laterals assumed a more leggy, upright growth, in contrast to the low, spreading branches of large diameter on the trees in the cultivated plots.

The growth of the trees on the various plots during the 4-year period of differential treatments is given in Table I. It will be noted that the best growth as judged by trunk circumference of the trees has been made on those plots without a summer cover. The trees in the cultivated plots that received stable manure are the largest of all. The trees in

the soybean plots made satisfactory growth, although they were not as large at the end of 4 years as those in cultivation. The growth of trees in buckwheat and crotalaria plots closely follows that of trees in soybeans. The trees in the legume sod plots made the smallest total growth during this period.

Effect on Soil Moisture:—In each of the last 3 years of the experiment there were periods of 1 month to 6 weeks during the growing season when there was a shortage of rainfall. Soil samples were taken during these periods to determine the percentage of soil moisture in the various plots. In 1934 there was very little rainfall during the months of July and early August. Soil samples taken under lespedeza and sweet clover showed the moisture content to be down to or below the wilting percentage in the first 2 feet of soil from July 5 to August 11, and under soybeans from July 16 to August 2. During the same period the moisture content of the soil of the cultivated plot at no time was within 4 per cent of the wilting percentage. (Fig. 1.)

Again, in 1935, (Fig. 2) there was a dry period from July 26 to August 26, but the early season rainfall had been near normal. Soil samples taken near the trees in the Lespedeza plots in soil occupied by

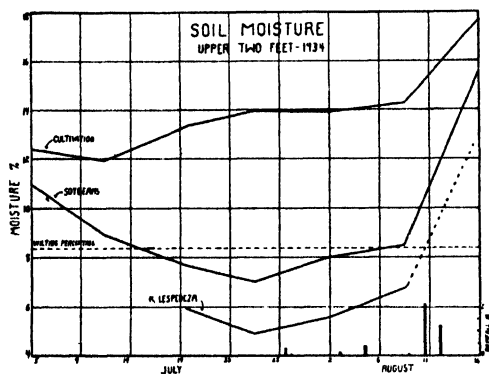


FIG. 1. Soil moisture upper 2 feet—1934.

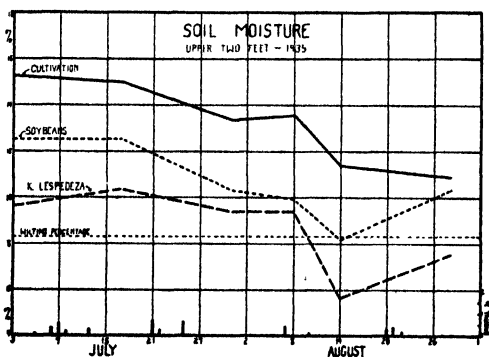


FIG. 2. Soil moisture upper 2 feet—1935.

both tree and cover crop roots showed the moisture content of the upper two feet of soil to be down to the wilting percentage from August 10 to August 27. This period would correspond with the period of final swell of the fruit. In a similar soil area on the soybean plot soil moisture reached the wilting percentage for only a short period, and at no time was the moisture content critical under cultivation.

The season of 1936 (Fig. 3) was in many respects like that of 1934. The June and July rainfall was below normal and soil moisture in the first 2 feet of soil in the lespedeza plots was down to the wilting percentage from June 26 to July 24, and again from August 7 to August 21. The soil moisture percentage of the soybean and cultivat-

ed plots, however, did not fall to the wilting percentage before August 14. The moisture in the sweet clover plot closely followed the curve for lespedeza in June, but after clipping and later discing up, it more closely paralleled the moisture curve of cultivation and soybeans.

It has been apparent in the 3 years of study on this soil type that the legume sods reduced the soil moisture by their active early season growth. During this period, the summer covers of soybeans, buckwheat, and crotalaria had either not been planted or were just becoming established, and consequently their effect on soil moisture was not noted until much later in the season.

Effect on Nitrates:—When trees are grown in grass or with cover crops, it is sometimes difficult to determine whether growth is affected more by moisture shortage or by the nutrient deficiency caused by the growing crops. In 1936, nitrate determinations were made on soil samples taken near the trees under the cover crops and were collected once a week for the period June 12 to August 21. The data presented in Table II are selected for a portion of this period.

The nitrate content of the soil on the various plots shows some variation in amount in the early part of the growing season. This is

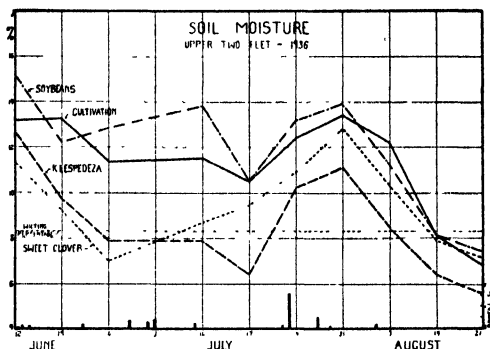


FIG. 3 Soil moisture upper 2 feet—1936

TABLE II—SOIL NITRATES IN UPPER TWO FEET OF COVER CROP PLOTS, 1936, (EXPRESSED IN PARTS PER MILLION)

Plot	Treatment	May 8	May 22	May 29	June 12	June 19	June 26
5	Manure	23.61	15.5	10.9	8.5	4.9	4.3
7	Cultivation	8.4	9.3	3.7	6.5	6.2	14.3
9	Lespedeza	10.3	17.6	3.9	7.2	2.9	12.1
11	Sweet Clover	9.1	2.9	5.7	9.0	6.8	9.0
13	Soybeans	10.6	14.5	9.4	17.3	12.4	11.5
15	Buckwheat	7.9	11.6	5.4	13.3	11.6	8.8
17	Cultivation	20.4	10.5	5.1	8.1	12.6	6.5
19	Crotalaria	6.4	5.6	8.7	9.1	13.1	10.9
Plot	Treatment	July 10	July 17	July 24	August 7	August 14	August 21
5	Manure	6.4	11.4	8.8	10.2	6.5	6.8
7	Cultivation	7.7	4.6	5.8	6.2	5.2	4.9
9	Lespedeza	4.7	1.7	3.8	4.9	6.1	0.9
11	Sweet Clover	7.9	17.7	18.4	9.8	15.4	21.1
13	Soybeans	12.8	14.0	14.1	9.6	14.2	10.1
15	Buckwheat	7.9	10.9	11.9	6.2	6.2	5.5
17	Cultivation	10.3	10.8	10.9	13.2	8.4	10.9
19	Crotalaria	13.1	13.1	17.8	9.6	12.8	4.9

not unexpected and is probably related to sampling soon after the spring fertilizers had been applied. In general, the nitrate under sweet clover and soybeans was higher throughout the season. There is a noticeable increase in the sweet clover plot after clipping in June and after disking under in early August. The cultivated plot 7 and the adjacent lespedeza plot 9 were lower in nitrate throughout the season. The buckwheat and crotalaria plots show no marked seasonal difference from the adjacent cultivated plot. The higher values on the summer cover crop plots in June are attributable to the nitrogen added at the time of seeding and for the crotalaria in July.

During the period of these studies the color of the foliage on all plots was a good green. There was no evidence of nitrate deficiency as manifested in foliage symptoms, and the leaves of trees in sweet clover in particular were a very dark green.

DISCUSSION

In the data presented here, emphasis has been placed on the effect of the various plants used as cover crops on soil moisture. When considered in relation to seasonal rainfall, it is apparent that on a somewhat shallow soil of this type with a maximum water-holding capacity of about 18 per cent, and a wilting percentage of 8.2 per cent, there have been periods in three of the four seasons when the soil moisture was reduced to or below the wilting percentage. In one season, 1934, the plants of both lespedeza and sweet clover reduced the soil moisture to the ultimate wilting percentage for this soil. During periods of moisture stress the effect could be observed not only in wilting of the cover crops but in slowing down and eventual cessation of terminal growth of the tree.

It is not to be inferred that all growth retardation on the various plots is to be ascribed to moisture shortage even though tree and leaf function are slowed up during periods of moisture shortage. The much better growth of the trees in the manure plot would indicate that trees on this soil have responded to the additional nutrients and mulch added in this form. Annual applications of nitrogen to the soil were considered adequate for trees of this age and plant growth was kept away by cultivating close to the trees. The growing cover crops would utilize some nitrogen applied to the tree and additional amounts of nitrogen would be required in the breakdown of the plant residue. Determinations made in 1936 did not indicate that soil nitrate was particularly low on those plots in which the trees made relatively poor growth in that year. However, nitrate determinations were not made in previous years.

There have, however, been distinct benefits from all cover crops in preventing erosion, in improving soil texture and physical condition, and in aiding in water penetration. These factors have not been measured quantitatively, the degree of benefit is one of observation.

Responses of Young Peach Trees to Nutrient Deficiencies

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ABSTRACT

This material will be published as a bulletin of the New Jersey Agricultural Experiment Station.

ONE-YEAR-OLD Elberta peach trees were grown in sand cultures in six different nutrient treatments: (a) A complete nutrient solution in which all essential elements were supplied in proportions favorable to good growth of peach trees, and five other series of treatments each containing all essential elements except one, *i.e.* (b) no nitrogen; (c) no calcium; (d) no magnesium; (e) no phosphorus; and (f) no potassium.

The effects of the various nutrient treatments upon composition, external appearance, and growth characteristics of peach trees were studied in detail.

No Nitrogen Treatment.—In the absence of an external supply of nitrogen, carbohydrates accumulated rapidly. This resulted in a yellowing of the old leaves, and later the young leaves. Typical purplish-red spots developed on the foliage. Stem growth was restricted in length and in diameter. Cell walls, in general, were abnormally thick. The roots were yellowish and slender but fairly extensive.

No Calcium Treatment.—Root growth was very strikingly affected by a deficiency of calcium. No long, free-growing roots were formed. New rootlets were abnormally short and thick, and soon began to die back from the tip. Stem growth was restricted in length but not very much in diameter. Within 6 weeks after the treatments were established the leaves on calcium deficient trees developed a characteristic type of discoloration. Following this, many of the stems and branches began to die back from the tips.

No Magnesium Treatment.—Neither small nor large 1-year peach trees stored much magnesium. Large, fast-growing trees developed a deficiency of this element as quickly as small trees. The leaves on the lower parts of the trees developed necrotic areas within 3 to 4 weeks and abscised very soon therefore. Magnesium was translocated from old to young tissues and was reutilized freely. The trees lacking magnesium were very deficient in carbohydrates. The stems continued to grow fairly rapidly in length but remained very slender. The roots exhibited a slight purplish tinge. Preceding the appearance of leaf lesions, considerable breakdown of root tissue took place.

No Phosphorus Treatment.—Phosphorus deficiency was manifest by the young peach trees very early in the experiment. The leaves were abnormally narrow and dark green, later they were somewhat tanned, and then, mottled in a characteristic manner. Defoliation occurred within 7 weeks. Following this, growth was renewed from supplies of phosphorus made available by proteolysis in stem and root

tissues. The growth of fibrous roots was restricted considerably by a deficiency of phosphorus.

No Potassium Treatment:—Plants in this treatment were characterized by a rapid accumulation of carbohydrates during the early part of the experiment, and then by crinkling of the foliage. Large and small necrotic, straw-colored spots developed on the foliage. In many cases, the leaf margins were scorched severely. Abscission zones usually developed around the necrotic areas and caused them to break loose from the healthy tissue. Following the appearance of leaf scorch and spotting, the trees began to grow actively and to improve in color. The trees exhibited two such cycles of growth and some evidence of a third. This cyclic growth was associated with the destruction of leaf tissue and the reutilization of potassium. Top growth continued over a long period of time, but the stems were very slender. The roots were slender and, in many respects, resembled those found in the no-nitrogen treatment.

Symptoms of Some Mineral Deficiencies in One-Year Elberta Peach Trees

By J. H. WEINBERGER and F. P. CULLINAN, *U. S. Department of
Agriculture, Beltsville, Md.*

IT is of considerable practical importance as well as academic interest to be able to recognize the disorders in plants resulting from mineral nutrient deficiencies. Fruit trees in every large fruit growing section in the country are subject to nutritional disorders under certain conditions, and the economic losses sustained are often great. Information making possible recognition of the symptoms and diagnosis of these troubles would seem highly desirable.

Recently the need for such information arose when a chlorosis affected peach trees growing on the experimental farm at Beltsville, Maryland. No complete description of the symptoms produced in peaches by lack of mineral elements with the exception of potassium and phosphorus (3) was available in the literature. It was decided therefore to study the disorders associated with the particular deficiencies by growing a series of peach trees in sand culture, omitting one of the essential elements from each nutrient solution.

METHODS

On April 2, 1936, 33 Tennessee "natural" nursery trees budded to Elberta were carefully selected for uniformity. The tops were cut back to the bud, the cut paraffined, and all secondary roots pruned severely. These trees were then planted in sand in 3-gallon glazed earthenware crocks, provided with a hole at the base for drainage. The sand had an analysis of 99.71 per cent silica, 0.005 per cent iron oxide, 0.012 per cent calcium oxide, and 0.006 per cent magnesium oxide. It had been treated with 5 per cent HCl and washed with distilled water until free from chlorides. Since preliminary experiments had shown that peach trees will grow satisfactorily in sand supplied with a solution having a composition of 0.003 molar mono-potassium acid phosphate, 0.006 molar calcium nitrate, 0.002 molar magnesium sulfate, 0.5 ppm. manganese sulfate, and 0.5 ppm. boric acid, this solution was used to furnish nutrients. Iron was supplied directly to the sand as ferric citrate. All salts except the last were C. P. grade.

All trees were given the above complete solution, omitting Mn, B, and Fe, until May 18, when the Elberta shoots were about 18 inches long. This normal growth prior to treatment seemed advisable in case subsequent lack of an element caused an early cessation of growth. Thus sufficient growth would be available to recognize symptoms or disorders. On May 18 the trees were separated into 11 groups of three trees each, and solutions lacking one particular element each were supplied to each of nine of the 11 groups. The elements omitted were N, P, K, Ca, Mg, Fe, S, Mn, and B. A complete solution containing all these elements and another solution lacking potassium but containing sodium also were included in the series. In each solution the concentration of nitrogen was held constant, and where one element

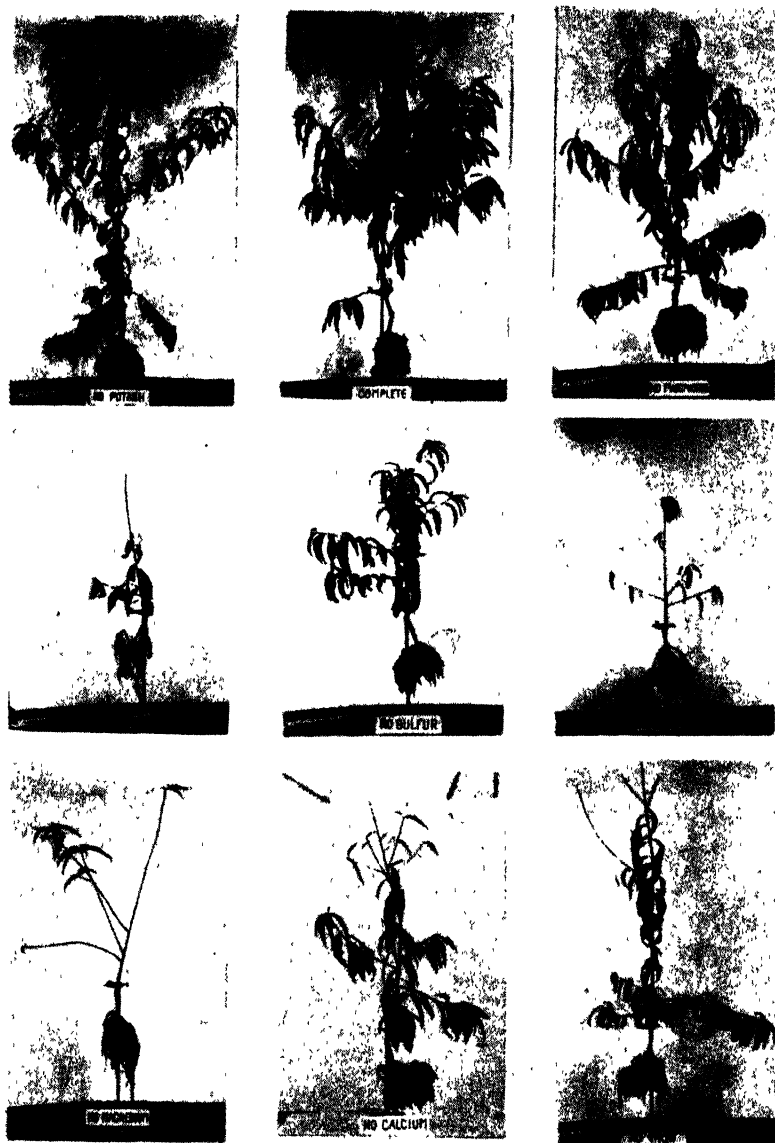


FIG. 1. Elberta peach trees grown in sand culture supplied with nutrient solution lacking the element indicated.

was lacking the necessary cation or anion balance was obtained by increasing the concentration of the other cations or anions, respectively. The reaction was adjusted to pH 5.6–6.0 and controlled by addition of potassium hydroxide.

In the early part of the experiment iron was supplied in the solution as ferrous sulphate, but under the conditions used the trees grew rapidly and this source of iron was not sufficient to prevent iron deficiency chlorosis. Later, iron was added directly to the sand as ferric citrate with satisfactory results. Two quarts of nutrient solution were supplied to each tree each day, using the previous day's leachings made up to volume with distilled water. Complete change of solution and flushing of sand with distilled water was effected each week.



FIG. 2. Leaves from trees grown in sand culture supplied with nutrient solutions deficient in (1) complete, (2) potassium, (3) calcium, (4) magnesium, (5) iron, (6) nitrogen, (7) sulfur, (8) manganese, (9) phosphorus.

RESULTS

The trees receiving a complete nutrient solution grew rapidly, and in September, when growth ceased they had made an average total branch growth of almost 25 feet. The leaves and branches were normal in every respect, the foliage dark green and vigorous in appearance (Figs. 1 and 2). Very few fibrous roots were found, and the root systems were small in comparison with the amount of top growth produced.

Three weeks after nitrogen was omitted from the nutrient solution the trees in the minus nitrogen group stopped growth and the leaves became pale green (Fig. 1). Gradually the leaves, veins and branches assumed a reddish tint and reddish brown spots appeared in the laminae. The leaves were smaller than normal and much twisted and curved (Fig. 2). Defoliation occurred early, the older leaves, after turning to an orange- or reddish-yellow color, dropping off first. A few fruit buds formed on terminal and lateral branches. A large amount of fibrous roots was produced—relatively three times as much by weight in proportion to top as the trees of the complete nutrient series. Many roots were decayed but new ones were growing when the trees were examined in September.

The trees that received a nutrient solution lacking phosphorus stopped growth earlier than the control, but made almost as much total

growth (Fig. 1). No marked disorder occurred. The leaves were large, deep green in color, and had a tough, leathery appearance (Fig. 2). They lacked the bright green appearance associated with vigorous growth, but otherwise seemed perfectly healthy and normal, remaining attached to the tree until the close of the experiment. A few fruit buds were formed. The roots were large, numerous, dark colored, and actively growing when examined. Wallace (5) reports that in severe cases of phosphorus starvation with apple trees the effects are as severe as, and similar to, nitrogen starvation.

Where potassium was lacking in the nutrient solution the trees made almost as much length growth as those of the control. The branches however were much smaller in diameter and the internodes were much longer, (Fig. 1). Early in the experiment the minus potassium trees developed a chlorosis resembling that caused by iron deficiency, and tests showed that this trouble could be corrected with either additional iron or potassium. Colby (2) experienced the same difficulty with prune trees in sand cultures and for 2 years was able to prevent chlorosis on minus potassium trees by additional iron. Apparently where an element, as potassium, is deficient, iron is less readily available and larger amounts are necessary. The first symptom produced by lack of potassium was a puckering of the lamina, caused by relatively greater growth of the intervascular tissue than of the veins. As growth proceeded the younger leaves no longer were puckered but were flat with the edges rolled inward and the axis curved backwards. While not chlorotic when iron was abundant, the leaves were lighter green than those of the control, and appeared thin and brittle instead of soft and pliable. The most marked symptom of potassium deficiency was the "leaf scorch", developed when cells in the extreme margin of the blades browned and died, and entire serrations lost their chlorophyll. Gradually the necrosis extended inward until entire margins to a depth of $\frac{3}{8}$ inch or more fell off in ribbons (Fig. 2). Minute brown spots appeared in the intervascular areas, and enlarged, and the dead tissue in the center of the spots shrank and fell out, perforating the blades. No other deficiencies produced symptoms of a similar nature. On some of the older leaves not affected with scorch a more or less distinct chlorosis gradually affected the area from the margin to a line half way to the midrib, the green color giving way to a dull yellow. The roots showed no distinctive deficiencies in growth, but root growth was small in comparison with the amount of top produced. Trees lacking potassium but given sodium were similar in every respect to those lacking both potassium and sodium.

The trees that had received no calcium in the nutrient solution continued to grow late in the season, but were somewhat dwarfed because the internodes were relatively short. For the same reason foliage was dense. The leaves were of normal size, except the very youngest, dark green in color, and tended to roll from the edges inward. Late in the season a large chlorotic area developed in the center of the younger leaves, and breakdown occurred immediately in the affected area (Fig. 2). About one-third of each lamina died, but before necrosis developed further the leaf abscised. Many roots had died, but also many were actively growing when the trees were examined. The presence of calcium

is usually considered necessary for root development, but in this study minus calcium trees had a larger proportion of roots to top than the complete nutrient trees. Possibly the calcium unavoidably precipitated in the sand when the trees received a complete solution had slowly become available later.

Lack of magnesium in the nutrient solution had an early and severe effect on the trees. In most instances the leaves that developed while the plants received a complete nutrient solution remained unaffected by later treatments. However, even these leaves were included in the defoliation which followed a general chlorosis appearing ten weeks after magnesium was eliminated from the nutrient solution. The chlorophyll disappeared rapidly from the intervascular areas but was retained in the vascular tissues, giving a dark green net-like impression of even the smallest veins on a light green to yellow background (Fig. 2). This closely resembled iron deficiency symptoms and it is possible that, although great excesses of iron were added to the cultures to overcome the chlorosis, the lack of magnesium may have interfered with iron availability. Before the chlorophyll had disappeared from the veins the leaves dropped off. In some leaves the entire lamina between large veins became necrotic. The older leaves fell off first, leaving the terminals late in the experiment in an active state of growth with five or six chlorotic leaves attached to each (Fig. 1). Roots were small and scarce but in an apparently healthy condition and actively growing.

The chlorosis of the leaves on iron deficient plants was similar in many respects to that observed on magnesium deficient trees; in fact, certain leaves in the two treatments were indistinguishable. However, the smaller veins on the minus iron trees usually did not retain their chlorophyll when the non-vascular tissue in the same region became chlorotic. Only the larger veins remained green, but, as growth continued and iron deficiency became more acute, chlorophyll was lost from the veins also (Fig. 2). Frequently the xanthophyll disappeared also and the leaves became almost pure white. Breakdown sometimes occurred in large sections of the leaf and patches of dead tissue dropped away. When defoliation occurred, the younger leaves were lost first, as contrasted with the dropping off of older leaves in the no magnesium treatment (Fig. 1). Roots appeared healthy and abundant and presented no distinctive characteristics.

Where sulphur was not supplied, terminal growth ceased early and the newer leaves turned pale green, very closely resembling leaves on trees lacking nitrogen. Small laterals developed near the tip of the terminal, having many small, pale leaves and giving a rosette appearance (Fig. 1). Gradually these leaves became tinged with red, scorched and withered. Large sections on some of the old leaves eventually died, shrank, and distorted the blades (Fig. 2). Defoliation had not occurred when the experiment was concluded. The roots were fine and numerous and of a very light, distinct shade of brown, which made them distinguishable from those of all other treatments.

Manganese deficiency symptoms were slow in appearing, though the trees had received no manganese from the start, except as impurities, and the interior of the crooks were carefully paraffined. The trees grew vigorously until late in the experiment, when the tips seemed

somewhat stunted. The leaves gradually assumed a dull, yellowish green color, quite different from the symptoms of any other mineral deficiency. More chlorophyll was present in the areas of the leaf adjacent to the large veins but was not confined to the vascular tissue (Fig. 2), while the remainder of the leaf was not particularly chlorotic but just a dull, lighter green. The pattern formed was also different and distinct from other deficiency chloroses. The roots appeared normal and healthy, and though abundant were not dissimilar from the control.

Trees not supplied with boron were rapidly and severely affected with disorders. Soon after differential treatments were started on other trees, and while growth was apparently normal, a dark green water-soaked spot, exuding sap, appeared on every growing tip about 1 inch back from the end. Gradually this spot enlarged, became brown and necrotic, and girdled the growing point. The leaves beyond the affected area wilted and died. Later the tip slowly died back for some distance (Fig. 1). Numerous lateral buds below started growth, but these also were similarly affected after developing a few small narrow leaves. Older leaves also developed small necrotic areas, irregularly shaped, which later dropped out and perforated the leaf. Most of the leaves were somewhat chlorotic. Defoliation occurred early, proceeding from the tips toward the base and including the most injured leaves. The bark became brown and rough with many small cork-like growths. The root system was very poorly developed, consisting chiefly of fibrous roots.

Copper (1) and zinc (4) are additional elements which have been used to correct physiological disorders of peach trees. Both are recognized as essential elements, but the evidence in the case of little leaf or rosette is not conclusive proof that the disturbance is a simple zinc deficiency. In the studies reported here, omission of copper or zinc from the nutrient solution had no observable effect on the growth of the trees.

In all but one of the mineral deficiency disorders described, greater or less amounts of leaf chlorosis were noted. In any attempt to diagnose the cause of a disorder, it is important to note the point of origin and the degree of the chlorosis, the pattern formed by the green and chlorotic areas, whether the younger or older leaves are more particularly affected, and the presence or absence of areas of dead tissue in the lamina. The progress of defoliation, the manner of growth, and the dying back of the branches are additional characters which should aid in the diagnosis of a disorder.

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Embryo Abortion in the Peach in Relation to Chemical Composition and Season of Fruit Ripening

By H. B. TUKEY and F. A. LEE, *New York Agricultural Experiment Station, Geneva, N. Y.*

ABSTRACT

The complete paper will appear in the *Botanical Gazette*

EMBRYOS of 10 varieties of peaches whose several seasons of fruit ripening extend from early to late were examined and chemically analyzed at or near the time the fruit was ripe. For comparison, embryos of a single late-ripening variety were analyzed periodically throughout the season.

Embryos of Elberta, representing late-ripening varieties increased rapidly in size during Stage II of fruit development, being .06 mm in length on June 26, 6.5 mm on July 10, 17.5 mm on July 21, and maximum size of 19.0 mm on July 31. The integuments had reached full size by the beginning of this period. Seed removed from the fruit and exposed in the laboratory before the embryo was full size lost moisture and the integuments collapsed upon the flaccid embryo as is characteristic of abortive seed. Embryos removed at maturity completely filled the integuments and were firm.

Embryos of the earliest ripening variety were abortive and disintegrated at fruit ripening. Embryos of later-ripening varieties were larger but failed to fill the integuments and would be classified morphologically as abortive. Embryos of still later-ripening varieties completely filled the integuments yet were somewhat flaccid, suggesting a slightly abortive condition. Embryos of the latest-ripening varieties appeared firm and completely filled the integuments.

At fruit ripening, embryos of a late-ripening variety, contained 45.03 per cent moisture, 30.67 per cent fat, 2.60 per cent nitrogen, 2.32 per cent sucrose, .23 per cent reducing sugars, and no starch. Embryos of early-ripening varieties showed by comparison a high moisture content and low content of fat, nitrogen, reducing sugars, and sucrose. In each successively later ripening variety the moisture content was lower, nitrogen higher, and fat higher until a level of about 30 per cent was reached. Reducing sugars did not appear in embryos of the earliest ripening varieties, appeared in traces in later varieties, remained at a fairly low and constant level in still later varieties, and then declined slightly in the latest ripening one. Sucrose appeared in the early varieties and remained at a nearly constant level in later-ripening varieties. No starch was detected in any of the samples.

If the moisture, fat, and nitrogen contents of the nine varieties are plotted with reference to the time of fruit ripening, and if the points are connected to give a curve, the composite graph so formed is similar to that for the development of a single variety (Elberta) at intervals during the season.

There appears to be a steady and similar increase in growth, loss of moisture, and accumulation of storage materials in all varieties at any

given date, and an abrupt check in these processes as the ripening date for each successive variety is reached.

The close similarity already observed in growth of embryos in different varieties, regardless of season of fruit ripening, is seen to extend to chemical changes within developing embryos, as well.

The data are discussed with reference to low germination of peach seed and embryo abortion in general.

Using the word "abortive" in its meaning of "checked or imperfectly developed", it would seem that an embryo which fills the integuments at fruit ripening, but which fails to store an adequate amount of food materials for germination and growth, is just as truly abortive as one which has failed to fill the integuments.

A Record of Peach Seed Germination Tests

By M. J. DORSEY, *University of Illinois, Urbana, Ill.*

IN the different methods of handling the seeds from the crosses in the Peach Breeding Project at the University of Illinois,¹ some things have been encountered which throw light upon the irregularities which have been obtained generally in germinating peach seeds under practical conditions. This paper is a brief record of some of the more significant points in the results obtained from 1913 to date.

The facts brought out by the previous research of most immediate concern in this connection are as follows: (a) Crocker (3) showed that peach seeds undergo the after-ripening process best at about 41 degrees F when cracked, and at 41 to 50 degrees F with the stone intact. The after-ripening was found to take place in 35 to 60 days in the former and in 60 to 100 days in the latter. (b) These results agree with the later findings of Crocker and Barton (4), who also report a higher germination of cracked seeds. (c) Crocker (3) says: "In general for rosaceous seeds it is well to free the seeds from the fleshy fruits and store them dry until the time for stratification." Haut (6) found drying before after-ripening had no marked effect upon germination. (d) Flemion (5) reported a peculiar dwarf-like growth in peach seedlings from non-after-ripened seeds.

RESULTS

Seed Germination from the Crosses:—The first point of interest is the difference in the percentage of germination obtained in 1913 and 1914 as compared with the years 1915 to 1922, inclusive, with similar parental combinations in the crosses. As will be seen from the headings in Table I the primary difference in procedure lies in the way the seeds were held before spring planting. All of the seeds were allowed to dry at room temperature before stratification, but in the first instance, they were mixed with sand and buried in pots for 2 to 4 months while in the latter they were planted in flats, in moist sand, and held above ground, thus subjecting them more directly to the prevailing temperature changes of the winter months. Since the temperature variables would be somewhat similar in each treatment, but less severe and abrupt in the buried seed, the possibility, in view of the findings of Tukey (7), of low temperature injury being the cause of poor germination in the seeds held in flats was suggested since after-ripening might be expected to occur during the exposure to outside temperatures. Accordingly, as will be seen from Table II, arrangements were made to test the killing point of peach seeds when after-ripened.

The second point of interest in Table I is the poor germination obtained in 1931 and 1932 (although in 1932 the seed number is small) with seeds which had not been after-ripened. The germination these 2 years may be compared with the three following seasons, 1933 to 1935

¹The writer hereby acknowledges his indebtedness to Mr. J. S. Whitmire, technical assistant in Plant Breeding for assistance in assembling data and in handling material.

TABLE I.—THE EFFECT OF DIFFERENT TREATMENTS UPON THE GERMINATION OF SEED OBTAINED FROM PEACH CROSSES

Year the Crosses Were Made	Number of Crosses	Time Seeds Were Held in After-ripening Medium	After- ripening Medium	After-ripening Treatments	Cracked or Not Cracked	Number Seeds in Treatment	Number Seeds Decayed— Stratification	Number Aborted Seeds When Cracked	Number Seeds Planted	Percent- age of Seeds Which Came Up
1913	28	118	Sand	Buried	Not cracked	706	46	7	653	60.03
1914	63	60	Sand	Buried	Not cracked	1207	49	1	1160*	48.10
1915	10	117	Sand	Above ground	Not cracked	40	—	—	40	.00
1916	51	117	Sand	Above ground	Not cracked	466	11	23	432	4.86
1917	14	93	Sand	Above ground	Not cracked	505	192	—	313	20.13
1919	39	113	Sand	Above ground	Not cracked	435	130	4	301	3.65
1920	27	100	Sand	Above ground	Not cracked	170	2	—	168	15.56
1922	48	109	Sand	Above ground	Not cracked	373	43	—	330	8.79
1931†	13	0	—	—	Cracked	145	—	11	134	2.24
1932†	5	0	—	—	Cracked	18	—	—	18	.00
1933	10	59	Peat	40 degrees F.	Cracked	1508	241	—	1267	83.27
1934	9	63	Peat	40 degrees F.	Cracked	641	100	—	541	61.00
1935	10	64	Peat	40 degrees F.	Cracked	1384	547	—	837	64.39

*Three double seeds.

†Held at room temperature until April, then cracked and soaked in water 48 hours before planting in soil.

TABLE II—RESULTS OF THE EXPOSURE OF ELBERTA SEED TO LOW TEMPERATURES TO DETERMINE THE APPROXIMATE KILLING POINT WHEN STRATIFIED IN PLANTING SOIL

Treatment of Seeds Before Planting	Total Number of Seeds in the Treatment	Number of Hours the Seeds were Held at Different Temperatures				Per Cent of the Seedlings Which Came Up in the Cracked and in the Un-cracked Series
		32 Degrees F	16 Degrees F	0 Degrees F	-10 Degrees F	
Not cracked	84 check	—	—	—	—	1.19
Not cracked	84	144	48	—	—	.00
Not cracked	84	144	48	48	—	.00
Not cracked	84	144	48	48	48	.00
Cracked	84 check	—	—	—	—	72.62
Cracked . . .	84	144	29	—	—	60.71
Cracked . . .	84	120	29	48	—	1.19
Cracked . .	84	120	29	48	48	.00

inclusive, when the seeds were after-ripened for 60 days or so at about 40 degrees F. Both lots were cracked although for the last 3 years the seeds were held in damp peat during after-ripening instead of sand. The drying before stratification in this case, as in the data presented in Table IV seems not to be an important factor in reducing the germination, thus checking with the results of Haut (6). It is probable since the seeds were cracked in 1931 and 1932 before planting that the omission of after-ripening was largely responsible for the poor germination.

TABLE III—SEED POSITION AS RELATED TO GERMINATION (VARIETY ELBERTA). THESE SEEDS WERE HELD DRY FOR 112 DAYS AT ROOM TEMPERATURE BEFORE BEING STRATIFIED IN PEAT. THEY WERE HELD UNCRACKED FOR 77 DAYS IN THE AFTER-RIPENING MEDIA AT 40 DEGREES F. BEFORE PLANTING

Total Number of Seeds in the Treatment	Number of Seeds Planted		Position of Seeds					Number of Seedlings Above Ground	Per Cent of Seeds Germinated
	Un-cracked	Cracked	Radicle Down	Radicle Up	Suture Down	Suture Up	On Side		
34	34	—	34	—	—	—	—	5	14.71
34	34	—	—	34	—	—	—	9	26.47
34	34	—	—	—	34	—	—	7	20.59
34	34	—	—	—	—	34	—	6	17.65
32	31	—	—	—	—	—	31	9	29.03
17	—	17	17	—	—	—	—	11	64.71
17	—	17	—	17	—	—	—	14	82.35
18	—	17	—	—	17	—	—	14	82.35
17	—	17	—	—	—	17	—	14	82.35
16	—	16	—	—	—	—	16	13	81.25

Freezing Tests:—In the freezing tests the seeds were obtained from peaches kept in bushel baskets in storage without drying for 196 days. The temperature level during this time was 35 to 37 degrees F. After planting both the cracked and uncracked series in flats, the seeds were then held at 32 degrees F for 3 days before being placed in the temperature rooms for the freezing tests. From the 32 degrees temperature

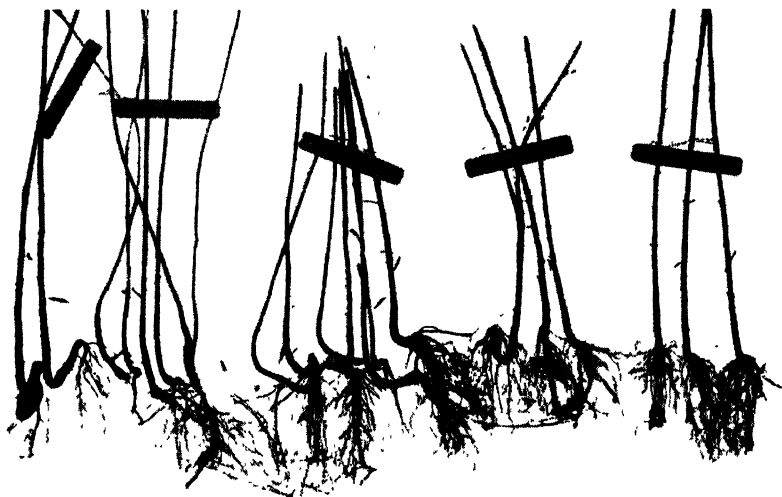


FIG. 1. The uncracked series. The position of the seed in each lot when planted, reading from left to right was as follows: radicle up; radicle down; seed on side; suture down, and in the last lot the suture side of the seed was placed upward.

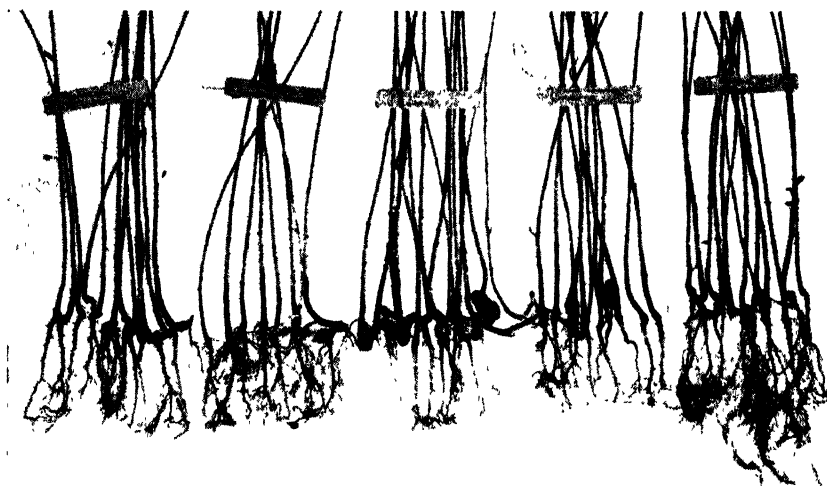


FIG. 2. The cracked series. The position of the kernel when planted was as follows: Reading from left to right as in Fig. 1: suture side up, suture side down, radicle up, radicle down, on side.

room the different flats were moved immediately to the next temperature level indicated in Table II and exposed to each variable 48 hours. After the exposure the flats given the different freezing treatments were moved to the greenhouse with the checks, a night temperature of 45 to 50 degrees F and a day temperature of 65 to 80 degrees F being maintained during the germinating period. Only one of the uncracked seeds germinated while those with the stone removed germinated very well at temperatures 16 degrees F or above. The other two lots exposed to zero and -10 degrees F were killed with the exception of one seed at the zero level. It should be noted that in this instance, the injury or killing took place at a higher temperature than reported by Tukey (7) for seed of the variety Chili. This evidence strongly suggests, in view of the germination obtained in 1913 and 1914 with similar crosses that at least a part of the difficulty from 1915 to 1922 may have been due to killing temperatures. Nursery men might well note these results in locations where fall planting would permit the seeds to be subjected to temperatures well toward 0 degrees F.

Position in Relation to Germination:—Since in planting seed from crosses with the care taken in work of this kind, it is possible to place them in the germinating media in any position, it seemed desirable to test position as possibly having a bearing upon the results of germination. These Elberta seeds used in this experiment were dried 112 days at room temperature before holding, uncracked 77 days in peat at about 40 degrees F for after-ripening. After this, they were then planted in soil in flats in the positions indicated in Table III and placed in a warm greenhouse during the germination period. As in the other tests the cracked seeds germinated best, but position seemed to be of no significance in determining the percentage of germination.

One very interesting thing, however, came out of this series, *viz.*, the relation of position to the straightness of the seedling. Those seeds with the radical pointing down tended to form nice straight seedlings while the others had a peculiar "kink" depending upon the position. This difference is shown in Figs. 1 and 2.

Miscellaneous Treatments:—Still other tests were made as to the effectiveness of some of the different treatments recommended from the more recent research. The different variables employed may be seen by referring to Table IV; the results of these tests may be briefly summarized as follows: (a) The tests of the longevity of Elberta seeds when held in a dry room with the stone intact showed that a few 2-year-old seeds germinated, but that 5-year-old seeds did not (line 32). (b) An after-ripening period of 29 days with Elberta seed was a little better than 20 and practically as good as 60 with both the 1- and 2-year-old seed (lines 17 to 30 inclusive). There is a suggestion in line 28 that a longer after-ripening period is better for 2-year-old seeds. (c) From the data presented in lines 1 to 6 it will be seen that both peat and sand were used in stratifying this series in which the seeds were not allowed to dry. Held in the media, uncracked during after-ripening, a part were then cracked from each media before planting; this latter treatment as in Crocker's experiments, markedly increased the percentage of germination in each case. This series was duplicated in lines

TABLE IV—RESULTS OF THE STRATIFICATION, CRACKING AND KEEPING TESTS WITH ELBERTA SEEDS

Line Number	Treatment of Seeds Before Stratification		Number Days Held in After-ripening Media	Stratification Media	Temperature Seeds Were Held Before and During Stratification		Condition of Seed Coat in Media	Number of Seeds in Treatment	Number Seeds Decayed in Stratification Aborted	Number Seeds Planted		Number Seeds Germinated	Percentage Germinated
	Days Dried	Days not Dried			Before	During				Un-cracked	Cracked		
1	—	111	62	Peat	Wet 32 degrees F.	40 degrees F.	Un-cracked	84	8	—	76	28	33.33
2	—	111	85	Peat	Wet 32 degrees F.	40 degrees F.	Un-cracked	84	—	—	84	62	73.81
3	—	111	86	Peat	Wet 32 degrees F.	40 degrees F.	Un-cracked	82	—	75	—	2	2.44
4	—	111	62	Sand	Wet 32 degrees F.	40 degrees F.	Un-cracked	84	—	—	84	34	40.48
5	—	111	85	Sand	Wet 32 degrees F.	40 degrees F.	Un-cracked	84	—	—	84	65	77.88
6	—	111	86	Sand	Wet 32 degrees F.	40 degrees F.	Un-cracked	82	—	75	—	3	3.66
7	111	—	62	Peat	Dry 70 degrees F.	40 degrees F.	Un-cracked	84	3	—	81	31	36.90
8	111	—	85	Peat	Dry 70 degrees F.	40 degrees F.	Un-cracked	84	2	—	82	63	75.00
9	111	—	86	Peat	Dry 70 degrees F.	40 degrees F.	Un-cracked	82	—	76	—	19	23.17
10	111	—	62	Sand	Dry 70 degrees F.	40 degrees F.	Un-cracked	84	3	—	81	51	60.71
11	111	—	85	Sand	Dry 70 degrees F.	40 degrees F.	Un-cracked	84	—	—	84	68	80.95
12	111	—	86	Sand	Dry 70 degrees F.	40 degrees F.	Un-cracked	84	—	84	—	24	28.57
13	—	111	39	Peat	Wet 32 degrees F.	40 degrees F.	Cracked	248	1	—	247	238	95.97
14	—	111	39	Sand	Wet 32 degrees F.	40 degrees F.	Cracked	250	1	—	249	215	86.00
15	110	—	41	Peat	Dry 70 degrees F.	40 degrees F.	Cracked	250	4	—	246	188	75.20
16	110	—	41	Sand	Dry 70 degrees F.	40 degrees F.	Cracked	250	2	—	248	189	75.60
17	115	—	20	Peat	Dry 70 degrees F.	40 degrees F.	Cracked	42	—	—	42	23	54.76
18	480	—	20	Peat	Dry 70 degrees F.	40 degrees F.	Cracked	42	—	—	42	2	4.76
19	115	—	29	Peat	Dry 70 degrees F.	40 degrees F.	Cracked	42	—	—	42	35	83.33
20	480	—	29	Peat	Dry 70 degrees F.	40 degrees F.	Cracked	42	—	—	42	3	7.14
21	115	—	40	Peat	Dry 70 degrees F.	40 degrees F.	Cracked	42	—	—	42	40	95.24
22	480	—	40	Peat	Dry 70 degrees F.	40 degrees F.	Cracked	42	—	—	42	4	9.52
23	115	—	50	Peat	Dry 70 degrees F.	40 degrees F.	Cracked	42	—	—	42	34	80.95
24	480	—	50	Peat	Dry 70 degrees F.	40 degrees F.	Cracked	38	—	—	38	2	5.26
25	115	—	60	Peat	Dry 70 degrees F.	40 degrees F.	Cracked	42	—	—	42	36	85.71
26	480	—	60	Peat	Dry 70 degrees F.	40 degrees F.	Cracked	42	—	—	42	2	4.76
27	115	—	70	Peat	Dry 70 degrees F.	40 degrees F.	Cracked	42	—	—	42	40	95.24
28	480	—	70	Peat	Dry 70 degrees F.	40 degrees F.	Cracked	42	—	—	42	11	26.19
29	115	—	78	Peat	Dry 70 degrees F.	40 degrees F.	Cracked	77	—	—	77	71	92.21
30	480	—	78	Peat	Dry 70 degrees F.	40 degrees F.	Cracked	18	—	—	18	0	.00
31	480	—	60	Peat	Dry 70 degrees F.	40 degrees F.	Cracked	180	96	—	84	8	9.44
32	1825	—	60	Peat	Dry 70 degrees F.	40 degrees F.	Cracked	180	179	—	1	0	.00

7 to 12 inclusive, with seeds which were allowed to dry before being placed in either sand or peat for after-ripening. With no marked difference in the percentage of seeds germinating between the cracked seeds in this lot and the former, it will be seen, however, that uncracked, dried seeds germinated better than the uncracked, undried seeds. (d) In the next series (lines 13 to 16 inclusive) comparison was made between seeds held wet at 32 degrees F, and dry at 70 degrees F, stratified in sand and in peat; all of them being cracked before planting in the flats. There is a slight gain in germination in this instance in favor of the wet seeds held in either peat or sand during the after-ripening period of 39 to 41 days. (See Haut 6). (e) There is no marked difference in these tests between peat and sand as a media for stratifying peach seeds during the after-ripening period.

Dwarf Seedlings.—In one series of germination tests run with Elberta seed in 1930, there appeared a number of seedlings similar to the semi-dwarf types which Miss Flemion (5) found to come from non-after-ripened seeds. Thinking at the time that these may produce semi-dwarf trees such as those reported by Blake (2) or as being comparable to Gage (Anderson and Dorsey (1)) which has a characteristically low-spreading top, a few were set in the nursery to test the possibility of this seedling growth habit being correlated with the low-spreading habit when mature. These trees were observed for four seasons, and all of them lost the short tufted growth habit after the first summer. It would seem safe to assume then that these seedlings came from non-after-ripened seed, and that this type of growth is, therefore, only a temporary matter. While no check was made as to the treatment of the particular seeds giving rise to the semi-dwarf seedlings, it may be stated that the series being run included cracked and uncracked seeds from both large and small peaches, and that the after-ripening temperature was 45 to 47 degrees F.

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Growth Study of the Apricot Fruit III. The Effect of Girdling

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AN earlier study (1) on the growth of the apricot revealed a growth periodicity which occurs regularly in the development of the fruit. The periodicity is characterized by an early rapid growth (Period I) followed by a period of less rapid increase (Period II) and this in turn by an accelerated increase (Period III). The approximate durations of these periods at Davis, California, are as follows: Period I, 6 weeks; Period II, 6 weeks; Period III, 3 to 4 weeks. Similar growth studies in peaches, plums and cherries have indicated that this cyclic nature of growth may generally be associated with the development of many drupaceous fruits. It does not occur with pome fruits. While the phenomenon has been generally recognized, little experimental work has been done to determine the factors responsible for this behavior. Why should apricot fruits, which have been growing rapidly for a period of 6 weeks, abruptly slow down and often cease to make any further diameter growth for the ensuing 6 weeks, and then with equal abruptness break into a period of very rapid growth that terminates with maturity?

Normally, all the fruits on a tree begin and terminate their periodic growth in unison. This synchronism that is so generally observed can be disturbed, and it has been demonstrated (2) that one can cause individual fruits to terminate their periods of growth in advance of the remaining crop by subjecting them to a warmer environment. The fact that the periods of fruit growth may be so manipulated and shifted would seem to indicate that they are not strongly associated with or produced by competing growth processes elsewhere in the tree. Changes of temperature did not remove or lessen the marked deceleration of growth, characteristic of Period II. Only the dates of its occurrence were advanced some 20 days by the exposure of individual fruits to a warmer night environment.¹ The seed development, characteristic of Period II, was advanced correspondingly by the warmer temperatures.

This paper presents results which seem to demonstrate the possibility of maintaining a rapid rate of increase and avoiding the marked deceleration of growth which defines Period II. This was accomplished by the process of girdling as described below.

PROCEDURE

1934:—On March 24, 1934, 30 fruits on an apricot tree (var. Tilton) were tagged and diameter measurements were made periodically thereafter for the purpose of establishing the average growth curve for

¹These temperature effects have been confirmed during the past season.

the season. These fruits were distributed on six branches around the tree.

When these fruits were found to be entering their second growth period on April 25, five additional branches varying from 20 to 40 mm in diameter at the base, were selected and girdled. Five fruits on each branch were tagged and their diameters measured.

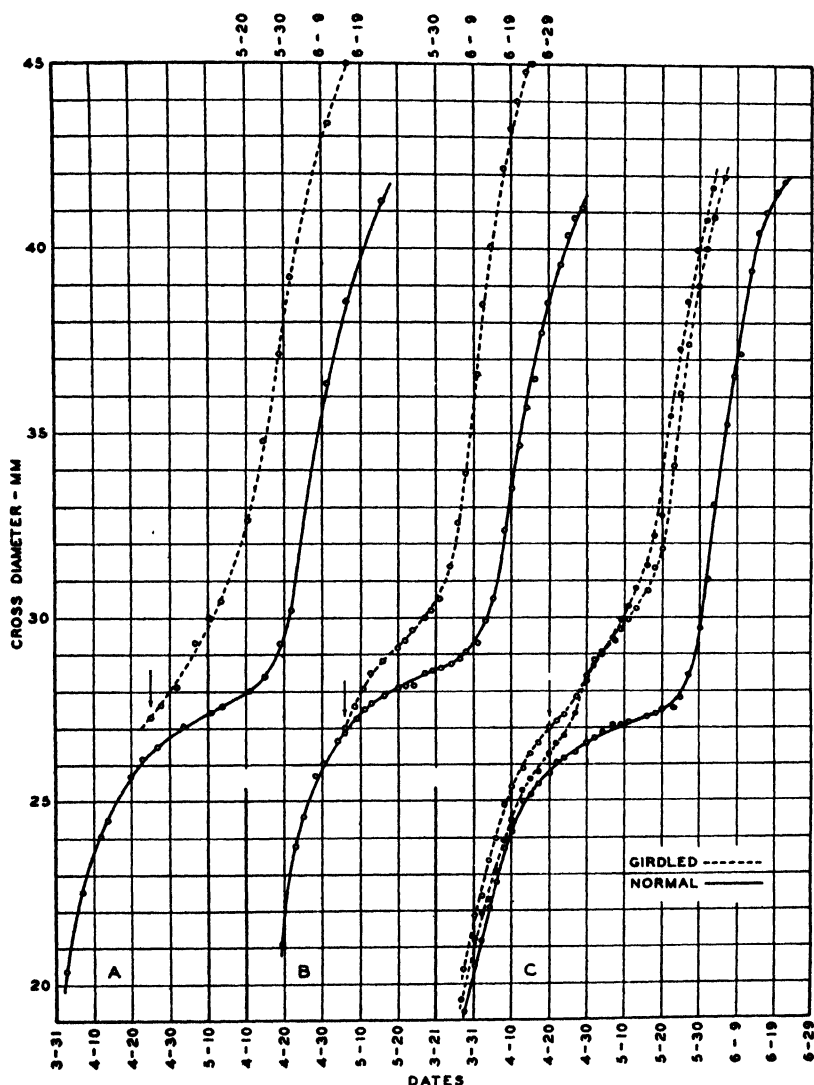


FIG. 1. Effect of girdling on growth of the apricot fruit. A, 1934; B, 1935; C, 1936. The arrows mark the date of girdling. The data indicate the possibility of maintaining a rapid rate of increase and avoiding the marked deceleration of growth which defines Period II.

One week after girdling, the fruits on four of the branches had diminished in average diameter and in some instances appeared wilted. This wilted condition continued for several days, but recovery was evident some 10 days after girdling in all but one limb which failed to mature its fruits. All others subsequently grew to maturity. The fruits on the fifth and *largest* limb showed no wilting, but on the other hand, an acceleration of growth when compared to the normal fruits. The growth data of these five fruits (Fig. 1A) indicated the possibility of modifying the normal growth behavior and securing some understanding of growth periodicity in the developing apricot fruit. The necessity of using large limbs for girdling was suggested by these preliminary studies.

1935:—On April 1, 30 fruits on an apricot tree (Var. Blenheim) were tagged and their diameters measured every 2 or 3 days thereafter until harvest time. These fruits were distributed on six different branches and no one limb showed any divergence in fruit growth from the average. On May 6, when it appeared that the rapid growth of Period I was over and the inception of the depressed growth of Period II was imminent, a limb with a diameter of 31 mm was selected and girdled. A strip of bark, 15 mm wide was removed and covered with a cold grafting compound. Ten fruits were selected at random and tagged for subsequent measurements. The growth data of these girdled and ungirdled fruits are presented in Fig. 1B.

1936:—On March 17, 1936, three similar limbs, approximately 45 mm in diameter, and arising from the same scaffold branch were selected and 15 fruits in each limb were tagged and measured every 2 or 3 days until maturity. On April 20, 7 days after the commencement of the second period of growth, two of the limbs were girdled. Again as in 1935 a strip of bark 15 to 20 mm wide was removed and the exposed area covered with a cold grafting compound. The diameter measurements are graphically presented in Fig. 1C. The growth of

TABLE I—DIAMETER GROWTH INCREMENTS OF NORMAL AND GIRDLED¹ APRICOT FRUITS.² (GIRDLED APRIL 20, 1936)

Dates	Growth Increment (Mm)		Increase Due to Girdling ¹
	Normal	Girdled ¹	
April 6–April 8.....	0.80±.04	0.87±.04	+ .07 ±.05
April 8–April 10.....	0.53±.03	0.54±.03	+ .01 ±.04
April 10–April 13.....	0.64±.03	0.62±.04	– .02 ±.05
April 13–April 15.....	0.28±.02	0.33±.03	+ .05 ±.03
April 15–April 17.....	0.23±.01	0.16±.03	– .07 ±.03
April 17–April 20.....	0.36±.03	0.43±.03	+ .07 ±.04
April 20–April 22.....	0.18±.02	0.27±.03	+ .09 ±.03
April 22–April 24.....	0.07±.02	0.14±.04	+ .07 ±.04
April 24–April 27.....	0.15±.01	0.53±.02	+ .38 ±.02
April 27–April 30.....	0.26±.02	0.66±.03	+ .40 ±.03
April 30–May 2.....	0.14±.02	0.43±.03	+ .29 ±.03
May 2–May 4.....	0.11±.02	0.29±.03	+ .18 ±.03
May 4–May 7.....	0.03±.02	0.42±.04	+ .39 ±.04
May 7–May 9.....	0.16±.01	0.38±.04	+ .22 ±.04
May 9–May 11.....	0.06±.02	0.29±.02	+ .23 ±.03

¹Fruits "normal" until April 20.

²Sample consisted of 30 tagged fruits, measured continuously.

the girdled and normal fruits together with the increase in growth of the girdled fruit is presented in Table I. The data indicate that previous to the time of girdling (April 6 to 20) the growth of the fruits on the two limbs was similar. There is a significant increase in the growth of the fruit in the ringed branch 7 days after girdling.

DISCUSSION OF RESULTS

1934:—From the data in Fig. 1A it may be noted that 10 days previous to girdling, the diameter of the fruit during Period I was increasing at the daily rate of .20 mm per day. During Period II the rate was .07 mm, approximately one-third that of Period I. However, the fruit on the large girdled limb (which showed no wilting) continued to grow rapidly at the rate of .17 mm, and on May 20 exhibited an additional increase, growing at the rate of .60 mm. The normal fruit showed a similar rate of growth on May 25, 5 days later than the girdled fruit. This was the date of inception of the third period.

Girdling has reduced rather strikingly the slowing down in growth which characterizes Period II. An acceleration commencing May 20 indicated the presence of other factors contributing to fruit-growth periodicity.

1935:—The 1935 data in Fig. 1B are based on more detailed measurements. An increase in the growth immediately followed girdling on May 6. The rate of growth was nearly doubled—the daily rates of increase for the girdled and normal fruits being 0.07 and 0.04 mm respectively. Again as in 1934, there is a further acceleration of growth which in 1935 occurred on May 31. This is the inception of Period III. A comparable acceleration in the normal fruits occurred on June 10. It is evident that while girdling reduces the duration of Period II by 10 days and increases the growth rate during this time, it does not eliminate its occurrence. The persistence of Period II is more apparent in the girdled fruit in 1935 than in 1934.

1936:—Further studies with a larger number of fruits in 1936 confirmed the results of the two previous years. The growth of the girdled fruit was so modified by girdling as to make it difficult to discern a well defined Period II. Girdling at the commencement of the depressed period of growth has produced a significant increase in diameter 7 days after the operation. The data in Table I and Fig. 1C suggest that girdling some 7 to 10 days prior to the termination of Period I might have completely eliminated any indication of Period II.

The acceleration in growth that marks the inception of Period III occurred 1 week earlier in the girdled fruit. It is concluded from 3 years' results, and with two different varieties, that changes produced by girdling are effective in altering the growth behavior of the apricot fruit, particularly in reducing the depressed period of growth. No chemical studies have been made. Curtis (3) has presented much data on the effects of girdling woody stems, and it may be concluded from his results, that of the changes produced by girdling (carbohydrate, nitrogen, hormone, etc.), that of carbohydrate accumulation above the girdle is a general occurrence. It was therefore of interest to attempt to obtain an increased carbohydrate supply to the fruit by another method, *viz.* increasing the leaf area per fruit.

EFFECT OF INCREASING THE LEAF AREA PER FRUIT

On March 29, 1934, 2 weeks previous to the occurrence of Period II, three uniform apricot trees (var. Royal) were selected and the fruit thinned as follows: The fruit on tree 1 was all removed except 30 to 40 fruits, about 4,000 being removed. Tree 2 was divided into two parts, the fruit on two large scaffold branches being untouched, and the fruit on the other half of the tree reduced to a total of about 30 fruits. Tree 3 was untouched, the total crop of approximately 4,000 fruits being left on the tree. There was therefore available for study a contrast of fruits with a very

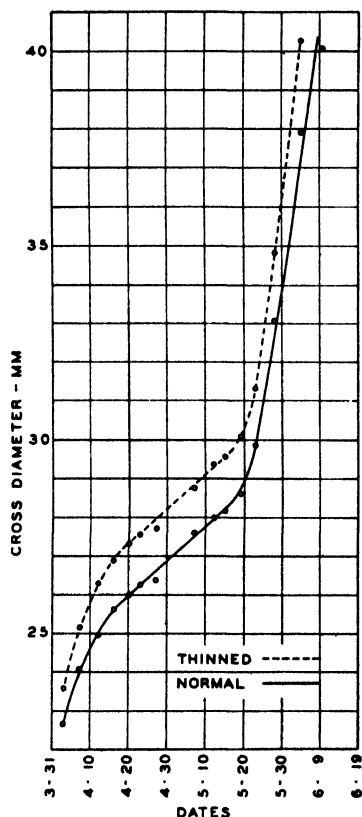


FIG. 2. Growth of apricot fruits as affected by an increased leaf area per fruit, produced by a very severe thinning of the fruits. The appearance of Period II remains unaltered. The dates of occurrence, the rate of diameter growth and the duration of Period II all remain unchanged.

large number of leaves—a condition favoring a high carbohydrate supply to the fruit—and of fruits with a limited leaf area and carbohydrate supply, plus a duplication of both these conditions on tree 2. That the leaf area was actually limiting was definitely demonstrated later by the greater growth made by the heavily thinned fruits.

Fifteen fruits on each of these treatments were tagged and their diameters measured periodically. These data are presented in Fig. 2. All fruits terminated their period of rapid growth (Period I) on the same date. The increased size of the thinned fruit was noticeable at the end of Period I. Neither the rate of growth during Period II nor the date of termination of this period was altered, and the depression of growth was as marked in the fruits with the large leaf area as in those with the small leaf area. Subsequently in Period III the rate of diameter increase was again greater in the thinned fruit. The data for tree 2 (the partially thinned tree) were identical with the corresponding treatment of trees 1 and 3 and are not reported.

Much of the carbohydrates formed during the depressed fruit growth period in the apricot tree having only 40 fruits probably combined with nitrogen in vegetative growth or was stored elsewhere in the tree. This is probably prevented by girdling. Can we conclude that the demand made by this growth and storage are responsible for the characteristic depressed period of

fruit growth? The possibility of advancing this period in individual fruits independently of other growth processes by enclosing fruits in temperature shelters would seem to contradict this hypothesis (2). The present complexity must await further experimentation for its solution.

The failure to obtain any alteration in the growth of the apricot fruit by so drastic a thinning treatment, and the striking acceleration produced by girdling, makes it evident that leaf area relationships and size of fruit on girdled and ungirdled branches cannot be compared. Girdling in the apricot has an effect on fruit growth that cannot be duplicated by merely increasing the leaf area per fruit. The lack of agreement between leaf area-fruit ratios on girdled and normal limbs as reported for peaches by Weinberger and Cullinan (4) and for cherries by Overholser and Claypool (5) would seem to confirm this.

EFFECT OF GIRDLING ON EMBRYO DEVELOPMENT

A rapid growth of the embryo is generally associated with Period II. It was therefore of interest to follow and compare the development of the embryo in relation to the acceleration in growth of Period II produced by girdling. Five fruits were periodically removed and examined.

At the time of girdling in 1936 the endocarp had completed its dimensional growth, the kernels (nucellus and integuments) had reached full size and the length of the endosperm (8 mm) was about one-half that of the nucellus and integuments (17.9 mm). The embryo had attained one-third (5.8 mm) of its final length at harvest time (17.3 mm). Only the data on embryo lengths are presented in Fig. 3. As far as dimensional growth is concerned the marked acceleration in the growth of the flesh produced by girdling is not reflected in embryo development. Since girdling was employed after the endocarp had reached maximum size, no increase could be expected in this component.

While there appears to be some definite relationship between the time of appearance of rapid embryo development and the inception of Period II, there are no data which disclose any association between seed development and the termination of this period of depressed growth. Tukey's (6) interesting procedure of destroying the embryo in peaches causing the fruit to drop in Period II and an acceleration in the rate of growth of the flesh in Period III, would indicate that the influence of the seed on the growth of the fruit extends essentially

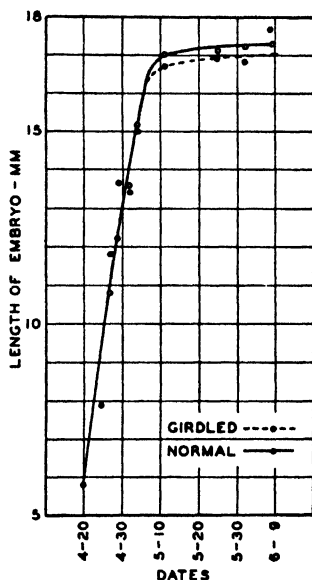


FIG. 3. Length growth of embryo from "girdled" and normal fruits. While the growth of the flesh was accelerated by girdling, no significant effect on the length growth of the embryo was apparent.

to maturity. It cannot be concluded from these apricot data, that girdling produced a release from Period II, the period of depressed growth, without causing any change in the embryo. The seat of the reaction which produces increased growth of flesh upon girdling may still be vested in the embryo.

EFFECT OF GIRDLING ON RIPENING

Girdling at the beginning of Period II increased the earliness of harvest some 14 days in 1935 and 1936. Notes on maturity of individual fruits made every 2 days at the time of their measurements in 1936, showed that the girdled fruit reached an "Eastern shipping ripe" condition 14 to 17 days in advance of the normal fruits. Fig. 4 shows this

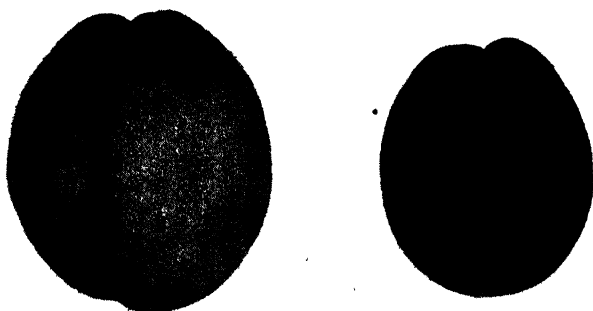


FIG. 4. Showing "girdled" fruit left, normal fruit right. Taken June 15, 1935, 40 days after girdling. Diameter of "girdled" fruit 40 mm, normal 30.5 mm. Note advanced maturity of "girdled" which was harvested 14 days earlier. The acceleration in growth rate seems to be immediate and may be noted from 6 to 10 days after girdling (Fig. 4). In 1935 the girdled fruit terminated Period II, 10 days in advance and ripened 14 days earlier.

advanced maturity of the girdled fruit a few days previous to harvest. Where earliness of harvest commands a marked premium, a judicious amount of girdling of apricot limbs might prove profitable. The girdle apparently heals the same season in which it is made and the limb sets fruit the following season.

SUMMARY

The growth of the apricot fruit is divided into three well defined periods. The first period is one of rapid increase, the second is characterized by a much arrested rate of increase, and the third by an accelerated rate of growth which continues until maturity.

The girdling of limbs greater than 30 mm in diameter, at the beginning of Period II, reduced the deceleration of growth so characteristic of this period. The increased growth due to girdling was evident 7 days after the operation.

Increasing the leaf area per fruit by a very severe fruit thinning in Period I did not alter the rate of diameter growth in Period II.

A discussion of possible carbohydrate changes produced by girdling in comparison to similar changes produced by increasing the leaf area per fruit is presented. Factors responsible for the decelerated growth of Period II are considered.

The advanced maturity of the fruit on girdled limbs and the judicious use of girdling in early apricot shipping districts is discussed briefly.

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"Kelsey Spot" of Plums in California

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FROM time to time, growers of shipping plums in California have reported loss from a spotting that develops just before picking. The trouble has been studied both by entomologists, who report no insect damage, and by plant pathologists, who find sterile tissue. Although the spot may occur on any part of the fruit, the distal end seems the most common portion to show it. In cases of slight injury the spot appears as a slight depression, sometimes reddish, underlaid by brown, necrotic tissue. In more severe cases the affected area is purplish red



FIG. 1. "Kelsey spot" on Kelsey plums from Newcastle, July 26, 1935, showing minor, moderate and severe damage.

and may involve a considerable portion of the fruit, either as separate or as coalesced spots. The injury is usually confined to about a quarter of an inch in depth below the skin in slightly affected fruit; but in severe cases, the brown tissue extends to the pit. This spot differs from sunburn in having sharp margins, depressed centers, and a purplish red color in contrast to the diffuse margins, normal shape, and brown color of sunburn. The damage is not confined, like sunburn, to exposed fruits, but may appear anywhere in the tree. It is usually worse, however, on the south and southwest sides. The appearance is shown in Fig. 1. In all cases severe enough to cause discoloration, the fruit is unsalable.

A survey of the important plum-growing districts of California (1935) showed the trouble to be fairly widespread in the interior valleys but, with a few exceptions, not commercially important. The greatest damage found was in an orchard of Burbank plums, where approximately 20 per cent of the fruits were affected.

The trouble appeared shortly after hot weather when the fruit was nearly ready to pick. Vigorous trees with large leaf areas were less affected than weak trees nearby. Orchards with summer covercrops showed less damage than nearby clean-cultivated orchards.

On the basis of experience with the Burbanks, Mr. E. F. Serr, Assistant County Farm Advisor in San Joaquin County, and I set up two experiments on a later variety. A Kelsey orchard near Lodi was chosen. Certain trees were given a heavy summer pruning in an effort to reduce transpiration. A burlap shelter over another tree was also used to reduce water loss. Although these trials were inconclusive, the summer-pruned trees apparently showed less damage from Kelsey spot than the unpruned ones. Because of exposure to direct sunlight, however, there were more sunburned fruits on the pruned trees than on the adjacent check trees. The shelter was more successful, not a single fruit showing a spot, whereas injury appeared on all the surrounding trees.

In another orchard of Kelseys on the same soil type, about a quarter of a mile away, "orchard grass" was growing vigorously. No injured fruits were found there. Both orchards were well irrigated. These findings seemed to confirm our hypothesis that the trouble might be a type of drouth spot.

In South Africa, a few months later, a paper by Dippenoar (1) described what seems to be the same thing, under the name "Kelsey Spot." The trouble is much worse there, and the work done has definitely established high temperature as the cause. If our observations in the field and the results of our experiments are reexamined from this point of view, all our data can be interpreted as indicating that heat damage rather than drouth caused the spot. Exposure of fruit to high temperatures in ovens in 1936 confirmed Dippenoar's findings; the trials indicated that 105 degrees F is about the critical temperature and that the time of exposure is very important. For example, Kelseys exposed to 107 degrees F for 5 hours (internal temperature not determined) showed no injury. Exposure for 15 hours gave 10 per cent damage and for 72 hours, 60 per cent. These fruits were picked slightly before the period when high temperatures seem to cause the most injury—that is, about 1 week or 10 days before commercial harvesting.

Observations in the plum-variety collection at Davis showed rather widespread damage among the Japanese plums, whereas there was little injury to the European sorts. These comparisons are valid only for varieties ripening at the same time, since only those subjected to hot weather during the period immediately before ripening are damaged. The relative susceptibility of the different varieties could be established only by observation over a number of years, correlated with temperature data, or by artificial heating of the fruit under controlled conditions. Certain varieties were damaged when there had been no air temperatures above 105 degrees F. This observation might be interpreted as evidence either that the threshold temperature causing injury to these varieties is lower or, as in the data reported by Dippenoar, that the fruit temperature may exceed the air temperature by several degrees.

The fact that spotting was much less in orchards visited in 1935 where summer covercrops were growing suggested a means of control. A trial block was established in the same block of Kelseys (near Lodi) where the preliminary trials had been conducted the year before. Half

this block was clean cultivated during the summer, and a summer covercrop was planted in the other half. In each half were set standard weather-bureau shelters containing thermographs about 5 feet from the ground. Both were set in the tree row as close to the north side of a tree as the branches permitted. Records were kept from the time of the first growth of the covercrop early in June until picking the last of July. These records showed an increasing temperature difference between the two plots as the covercrop grew. The difference was greater, also, at high temperatures than at low ones. Below 80 degrees F there was little or no difference. At temperatures above 100 degrees F the difference was commonly 4 degrees and on one occasion reached 6 degrees. Not only was the temperature higher in the clean-cultivated block, but the time during which the temperature was above a given point was longer. For example, on July 19, the only day the temperature in the covercrop block reached 105 degrees, a maximum of 106 degrees was recorded, and the temperature remained above 105 degrees in this plot for 1 hour. In the other plot it remained above 105 degrees for 6 hours, with a maximum of 110 degrees. The maximum temperature recorded for the covercrop plot, except for July 19, was 102 degrees. During the critical period, the second week before picking, the temperature in the cultivated plot reached 105 degrees or above on 5 of 6 consecutive days. This temperature effect of the covercrop may be sufficient to account for the observed differences between the two plots. Only one specimen could be found in the covercropped area, whereas about 1 per cent showed damage in the clean-cultivated plot. Possibly reflection and radiation from the bare ground as well as heating the adjacent air may be factors in producing injury.

It should be noted that the blocks used were relatively small and that the differences in temperature recorded might be smaller, because of air movement from one plot to the other, than might be found if larger areas had been used.

This test and the numerous field observations made in other places seem to establish the fact that the amount of injury can be greatly reduced—and in many cases, eliminated—by summer covercrops. Under conditions existing in the interior valleys and foothills of California, this method is practicable only where irrigation water is available, because there is little or no rain during the summer months. In years when summer temperatures at the critical period for a variety are not excessive, there should be no injury even without a covercrop. Even in years of generally high temperatures, it is not likely that all varieties in a given district will be affected. The damage, judging by past experience, is not liable to be excessive in any California orchard; but where past experience has indicated the desirability of some control and where abundant water is available, the use of a summer covercrop seems to minimize the injury.

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Some Results on Washing Cherries for the Removal of Spray Residue

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THERE seems to be no problem for the grower in the removal of spray residue from cherries when the fruit is canned or cold packed. Apparently the washing treatments employed prior to preserving by either of these methods is sufficient to remove the residue well below the tolerance.

A considerable acreage of sweet cherries and English Morello cherries is grown in the Hudson Valley fruit section of New York State. These varieties are not used by the canners or cold packers. They are grown solely for the fresh fruit trade. During the past several years the growers have found it rather difficult to apply as much spray as they considered necessary for the control of the cherry fruit flies without having the fruit carry residue in excess of the tolerance at harvest. In several cases it has been necessary for the growers to recondition the fruit before offering it for sale.

These first attempts to wash cherries were not entirely satisfactory. Some of the washing solutions used failed to reduce the residue sufficiently, while others which were more effective in residue removal caused the fruit to crack or destroyed its attractive appearance. In the event that a dry season should prevail or in case an extra application of spray was needed to control the fruit flies, a serious residue problem might result in many orchards. The general situation seemed to warrant some experimental work on the practice of washing cherries.

Robinson (1) working in Oregon reported that sprayed sweet cherries could be satisfactorily cleaned of arsenical residue by dipping the fruit in a 0.3 per cent solution of hydrochloric acid. This solvent did not cause cracking of the cherries under Oregon conditions, unless a rain occurred during the night or immediately before picking. It was pointed out that when such weather conditions prevailed, cracking of the fruit during the washing process could be avoided by allowing the cherries to stand for an hour or more after picking before attempting to wash them.

The dipping method was used in all the tests reported here, because no commercial fruit washing machines adapted to cherry washing were available. The equipment consisted of two vats and several dipping trays. One vat contained the washing solution and the other clear water for rinsing. Agitation during the washing process was secured by sousing the trays of cherries up and down as they were passed from one end of the vat to the other.

Hydrochloric acid was the first solvent tried because of the wide use of this material in removing spray residue from fruits. Table I gives a few results secured when a solution of less than 1 per cent hydrochloric acid was used. In addition to the time the fruit was exposed to the acid bath all samples were dipped in rinse water for a period of 1 minute. Neither 2 or 3 minute periods of agitation in a 0.5 per cent solution of hydrochloric acid removed sufficient quantities of residue from the Montmorency and English Morello cherries. The Schmidt and Wind-

sor varieties were satisfactorily cleaned by a 3 minute exposure to the acid bath, but these sweet cherries carried a smaller residue load than the sour varieties and a slightly stronger acid solution was used in the case of the sweet cherries. These and other preliminary results indicated that a 0.5 per cent solution of hydrochloric acid could not be depended upon to remove spray residue from cherries when the dipping method of washing was employed. The difference in these results and those reported by Robinson may have been due to the large amounts of sulphur fungicides included with the lead arsenate spray in the eastern sections or possibly to some small amounts of naturally occurring salts in the wash water that may have influenced the efficiency of the acid. The 0.75 per cent acid solution caused a few of the Schmidt and Windsor cherries to crack.

TABLE I—THE EFFECT OF A DILUTE SOLUTION OF HYDROCHLORIC ACID ON THE REMOVAL OF ARSENICAL RESIDUE FROM CHERRIES, 1935

Variety	Time Exposed to Acid Bath (Minutes)	HCl (Per cent)	As ₂ O ₃ * (Grains per Pound)	Pb.* (Grains per Pound)
Montmorency	Unwashed	—	0.034	0.079
Montmorency	2	0.5	0.007	0.024
Montmorency	3	0.5	0.007	0.019
English Morello	Unwashed	—	0.086	0.224
English Morello	2	0.5	0.015	0.075
English Morello	3	0.5	0.013	0.052
Schmidt	Unwashed	—	0.008	0.023
Schmidt	3	0.75	0.001	0.009
Windsor	Unwashed	—	0.006	0.022
Windsor	3	0.75	0.001	0.007

*Present tolerance: As₂O₃ = .01 grains per pound of fruit.
Lead = .018 grains per pound of fruit.

Further tests were made with hydrochloric acid on other lots of cherries. A 1 per cent solution was used in all cases since weaker solutions proved to be not very effective in residue removal. Counts were made on the amount of cracking caused by the treatments. Table II gives some of the results of these tests. The 1 per cent solution was more efficient in residue removal than the 0.5 per cent solution but in several cases the stronger solution failed to reduce the lead residue below the tolerance. If hydrochloric acid had proved to be dependable in residue removal its use for this purpose would nevertheless be unsatisfactory due to the heavy loss from cracking of fruit caused by the wash. Cherries washed in hydrochloric acid solution also lost their bright finish, becoming dull and unattractive. Many showed acid injury around the lenticles in the form of a fine pitting.

Several wetting agents were used in a few tests with hydrochloric acid. These materials increased the effectiveness of the acid in residue removal but they also caused an increase in the amount of cracking. These tests suggested that some acid less active than hydrochloric acid used in conjunction with a wetting agent might make a satisfactory

TABLE II—RESULTS OF WASHING ENGLISH MORELLO CHERRIES IN A 1 PER CENT SOLUTION OF HYDROCHLORIC ACID. 1935 AND 1936

Time Exposed to Acid Bath (Minutes)	Time Elapsed Between Pick- ing and Wash- ing (Hours)	Per cent Cracked	As ₂ O ₃ (Grains per Pound)	Pb. (Grains per Pound)
Unwashed.....	—	—	0.028	0.081
3.....	1	34.2	0.008	0.033
3.....	42	7.4	0.003	0.006
Unwashed.....	—	—	0.026	0.070
3.....	1	10	0.005	0.018
3.....	1	19.7	0.003	0.017
Unwashed.....	—	—	0.034	0.110
3.....	1	24.6	0.005	0.023
3.....	2	25.5	0.008	0.027

TABLE III—THE EFFECT OF ACETIC SOLUTIONS USED WITH CERTAIN WETTING AGENTS ON THE REMOVAL OF SPRAY RESIDUE FROM CHERRIES AND THE CRACKING OF THE FRUIT. 1936

Variety	Treatment	Time Elapsed Between Picking and Wash- ing (Hours)	Time Exposed to Acid Bath (Minutes)	Per cent Cracked	As ₂ O ₃ (Grains per Pound)	Pb. (Grains per Pound)
Windsor.....	1 per cent CH ₃ COOH	2	3	0	—	—
Windsor.....	3 per cent CH ₃ COOH	2	3	0	—	—
Windsor.....	8 per cent CH ₃ COOH	1	5	2	—	—
Mont- morency...	Unwashed	—	—	—	0.046	0.122
Mont- morency...	3 per cent CH ₃ COOH	1	3	0	0.004	0.013
Schmidt.....	Unwashed	—	—	—	0.052	0.132
Schmidt.....	3 per cent CH ₃ COOH	1	3	0	0.005	0.018
Eng. Morello	Unwashed	—	—	—	0.033	0.056
Eng. Morello	1 per cent CH ₃ COOH + Nekal*	1	3	0	0.004	0.006
Eng. Morello	2 per cent CH ₃ COOH + Nekal*	1	3	0	0.003	0.006
Eng. Morello	Unwashed	—	—	—	0.026	0.043
Eng. Morello	1 per cent CH ₃ COOH + Igepon*	1	3	0	0.003	0.007
Eng. Morello	2 per cent CH ₃ COOH + Igepon*	1	3	0	0.003	0.006
Schmidt.....	Unwashed	—	—	—	0.057	0.144
Schmidt.....	3 per cent CH ₃ COOH + Aresket*	immedi- ately	3	0	0.005	0.011

*Wetting agent used in the textile industry.

wash for cherries. Acetic acid was tried in this way. Table III gives some of the results.

Dilute solutions of acetic acid when used alone or in combination with wetting agents did not cause the cherries to crack. The strength of the acid bath was raised to 8 per cent and trays of Windsor cherries were exposed to this solution for 5 minutes before any cracking of the fruit was noticed. This treatment caused only 2 per cent of the fruit to crack.

When acetic was used without the wetting agent, a solution of at least 3 per cent was required to remove heavy loads of residue satisfactorily. It will be noted in Table III that one lot of Schmidt cherries containing 0.132 grains of lead per pound of fruit just met the tolerance for lead (0.018 gram per pound) after being washed in a 3 per cent solution of acetic acid for 3 minutes.

When wetting agents were added to the acetic acid bath a 1 per cent solution of acid seemed to be just as effective in residue removal as stronger solutions. In all tests, acetic acid solutions with wetting agents added reduced the residue load well below the tolerance. The addition of the wetting agents to the bath improved the finish of the fruit. The washed cherries were bright and attractive.

Nekal and Aresket were the best wetting agents of the three used. Igepon gave excellent wetting properties to the bath but small amounts of this material produced a heavy foam which got into the rinse vat causing considerable inconvenience.

Two tons of Schmidt cherries and one-half ton of English Morellos containing arsenic and lead residues 4 to 8 times the tolerance were satisfactorily washed during the 1936 harvest season with a 1 per cent solution of acetic acid plus a wetting agent. These cherries reached the market in excellent condition and the growers received the top prices for them.

Several alkaline materials, such as soda-ash, sodium silicate and tri-sodium phosphate have been used in removing spray residue from apples. These were tried in a limited number of tests for cherry washing. While the residue was not always reduced below the tolerance, these alkaline washes did not crack the fruit and they usually improved the appearance. For this reason they are considered promising for this purpose.

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A Progress Report on Comparisons of High-Calcium and High-Magnesium Limes in Bordeaux on Sour Cherry, and in Zinc-Lime and Iron-Lime Mixtures on Peach¹

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THE use of high-calcium lime in spraying is a generally recommended practice. Dutton and Farish (1) concluded from experiments conducted in 1934 and 1935 that (a) "Bordeaux of any kind may accenuate drought conditions, but dolomitic hydrated lime is equal to or possibly better than high-calcium lime for use in bordeaux on Montmorency cherries, and (b) in arsenical correctives on peach, high-calcium lime seems best with iron-lime and dolomitic lime best with zinc-lime."

INFLUENCE OF HIGH-CALCIUM LIME AND HIGH-MAGNESIUM LIME BORDEAUX ON MONTMORENCY CHERRIES

The following is a progress report for 1936 on work on the same experiments reported by Dutton and Farish (1). The orchard is located on a fertile sandy loam. The trees are 5 years old, have not been fertilized since set, and have received little pruning. The plots consist of 12 trees each. No duplications of plots were made. Plots of similar concentration of the two kinds of bordeaux are adjacent to one another.

Bordeaux mixtures, 2-3-100, and 4-6-100, and 8-12-100 were prepared from both high-calcium and high-magnesium lime. Weather conditions were similar to those of 1934; high temperature, low rainfall, and low humidity to the middle of August. Heavy rainfall occurred in September.

Observations.—Comparisons were made on size of fruit, yield, per cent solid in fruit, leaf fall, shoot and trunk growth. Leaf counts were made on 600 spurs and 300 shoots. Shoot growth was measured on 240 shoots, size of fruit on 1,200 cherries per plot. The yield is the total weight of fruit harvested. Trunk circumferences were measured on all trees. Per cent solids was measured by taking the refractive index of expressed juice and the size of pits by displacement of 100 pits in water.

Influence on Leaf Fall.—The most noticeable effect of the two kinds of bordeaux was in the number of leaves retained on spurs and twigs. The dry weather to the middle of August was unfavorable for the development of foliage injury. By September 1st, however, the loss of leaves from trees in the different plots was readily noticeable and by October 16th the trees in the high-magnesium lime bordeaux sprayed plots retained two to three times as many leaves per spur as the trees in the high-calcium lime bordeaux plot. No constant relation existed between leaf fall and the concentration of either of the bordeaux mixtures. It was observed that defoliation occurred first on the spurs on older wood and as the season advanced on spurs on the younger wood and then on the shoots. As seen in Table I less defoliation occurred on

¹Journal Article No. 277 (n.s.) from the Michigan Agricultural Experiment Station.

TABLE I.—THE EFFECT OF BORDEAUX SPRAYS ON MONTMORENCY CHERRY TREATMENT

	2-3-100				4-6-100				8-12-100			
	High-Calcium Lime Bordeaux		High-Magnesium Lime Bordeaux		High-Calcium Lime Bordeaux		High-Magnesium Lime Bordeaux		High-Calcium Lime Bordeaux		High-Magnesium Lime Bordeaux	
	Sept. 2	Oct. 16	Sept. 2	Oct. 16	Sept. 2	Oct. 16	Sept. 2	Oct. 16	Sept. 2	Oct. 16	Sept. 2	Oct. 16
Average number of leaves per spur	2.1	1.4	3.2	2.9	1.9	0.7	3.6	2.2	1.9	1.1	3.8	2.9
Average number leaves per shoot. . .	15.9	14.2	16.7	16.4	14.7	9.4	16.4	10.5	14.4	8.7	16.9	10.9
Average shoot growth (inches)	16.8		16.5		16.4		16.0		14.6		15.0	
Average increase in trunk circum- ference (inches) per tree October 1935 to October 1936.	1.75		1.9		1.52		1.84		1.45		1.72	
Average yield (pounds)	5.72		6.89		6.33		7.89		4.49		6.88	
Number cherries to the pound in fruit	169		167		184		180		194		182	
Per cent total solids.	19.0		20.0		21.0		21.5		22.75		23.25	
Size of pits cc displacement of 100 pits in water.	19.5		19.5		19.0		20.0		19.0		19.0	

the shoots than on spurs on all the plots by September 2, but the high calcium lime plot showed more loss of leaves per shoot than the high magnesium lime plot. By October 16 considerable defoliation occurred on shoots on all plots but the loss, as with the spurs, was greater on the high-calcium lime bordeaux sprayed trees.

The amount of copper retained on the foliage is interesting in relation to foliage injury. An analysis of the foliage for copper October 1st showed the following amounts in per cent of dry weight of the sample.

Treatment		Per Cent of Copper
4-6-100	High-calcium lime bordeaux	.158
4-6-100	High-magnesium lime bordeaux	.313
8-12-100	High-calcium lime bordeaux	.312
8-12-100	High-magnesium lime bordeaux	.543

The copper in the high-magnesium lime bordeaux is apparently held in a less soluble form which is less toxic to foliage and not as readily washed off or absorbed as the copper in the high-calcium lime bordeaux.

Influence on Shoot Growth:—The difference in the average shoot growth on the trees sprayed with the same concentration of high-calcium and high-magnesium lime bordeaux is small. The shoot growth on the 2-3-100 and 4-6-100 is slightly longer and on the 8-12-100 slightly shorter than on the similar plots of high-magnesium lime bordeaux.

The effect of the concentration of the bordeaux is in accord with that found by Dutton (1), that is, the greater the concentration of the spray the shorter the growth. This occurs with both kinds of bordeaux. This difference in growth must be due to a direct effect of the spray and not to defoliation, since shoot growth had ceased before any leaf-fall occurred.

Influence on Trunk Growth:—The actual increase in trunk circumference shows a more consistent relation to both concentrations and to kinds of bordeaux than does shoot growth. The higher the concentration the less growth of trunk with both kinds of bordeaux. A comparison of the two mixtures of similar strength shows that the increase in trunk circumference was greatest in all plots on the trees sprayed with high-magnesium lime bordeaux.

Effect on Yield:—The yield in pounds per tree is of no significance since the trees are young and have not produced what could be called a commercial crop. It is interesting to note, however, that the trees sprayed with a high-magnesium lime bordeaux produce a larger yield than the trees on corresponding plots receiving high-calcium lime bordeaux.

Size of Fruit:—The size of cherry appears to be definitely influenced by the concentration of the bordeaux, the largest fruit being produced on trees sprayed with 2-3-100 and the smallest on trees sprayed with the 8-12-100 mixture. This relation occurs with both kinds of bordeaux. The size of fruit produced on trees sprayed with high-calcium

lime and high-magnesium lime bordeaux on the 2-3-100 and the 4-6-100 plots is almost identical, while the 8-12-100 high-calcium lime bordeaux sprayed trees produced slightly smaller fruit. Since bordeaux has been shown to accentuate drought effects, it is probable that the higher concentration would have a greater effect on transpiration rate and in that way influence the size of the fruit.

Per cent Solids.—The per cent solids, like the size of fruit, is correlated with the concentration of bordeaux; the 2-3-100 producing fruit with the lowest per cent and the 8-12-100 the highest per cent of total solids. There also appears to be a relation to the kind of bordeaux. Fruit produced on the high-magnesium lime bordeaux plot although slightly larger in size is also slightly higher in the per cent of total solids.

Size of Pit.—No noticeable differences were found in size of pits.

ARSENICAL CORRECTIVES ON PEACHES

The use of zinc-lime and iron-lime mixtures prepared from both high-calcium and high-magnesium lime as a corrective for arsenical injury on the Rochester variety of peaches was continued in 1936. Two applications were made; one at the shuck-fall stage consisting of lead arsenate and a corrective, and a second application 2 weeks later which included flotation sulphur in addition. Concentrations of 4-4-100, 6-6-100, and 8-8-100 were used with both kinds of lime.

The low temperatures during the winter of 1935 and 1936 caused considerable winter injury to the trees. The trees were not pruned, shoot growth was short, a heavy crop of fruit was produced, and the foliage had a dark green healthy appearance throughout the season.

The dry weather during June, July, and part of August was unfavorable for the development of arsenical injury. All the plots were similar in appearance, retaining their foliage throughout the summer. A general examination August 14th showed an occasional leaf with arsenical injury in the form of round dead areas and holes where the injured tissue had fallen out. No shoot injury was observed on any of the plots. No characteristic arsenical injury was found on the peaches. The only injury was an occasional peach with cracked flesh on the side exposed to the sun. This injury occurred also on trees receiving sulphur only and consequently could not be credited to the arsenical spray. Counts were made on 50 shoots per tree September 19th, and 20th on the number of nodes and leaf scars from which leaves had fallen.

The results are not in accord with those reported by Dutton and Farish (1) in 1935. The difference in rainfall for the 2 years may account for the variation in results or it may be an indication that over a period of years one lime is as good as the other for use as a corrective for arsenical injury. The results are given in Table II.

A satisfactory commercial control was obtained on all plots receiving zinc sulphate and iron sulphate, lime mixtures. The best control was obtained with the 6-6-100 and 8-8-100 iron sulphate, high-magnesium lime mixture. These two plots showed no more defoliation than trees receiving flotation sulphur only. The iron sulphate high-calcium lime mixture of the above concentrations showed considerable more defoliation while no differences occurred between the two lime mixtures of lower concentration. The zinc sulphate high-calcium lime mixture

TABLE II—INFLUENCE OF HIGH-MAGNESIUM AND HIGH-CALCIUM LIMES IN COMBINATION WITH ZINC SULPHATE AND IRON SULPHATE AS AN ARSENICAL CORRECTIVE ON PEACHES

Corrective	Kind of Lime	Pounds of Lead in 100 Gallons	Actual Leaf Fall 100 Shoots
Zinc-lime.....	High-calcium	2	127
4-4-100.....	High-magnesium	2	196
Iron-lime.....	High-calcium	2	157
4-4-100.....	High-magnesium	2	157
Zinc-lime.....	High-calcium	2	125
6-6-100.....	High-magnesium	2	172
	High-calcium	3	255
	High-magnesium	3	204
Iron-lime.....	High-calcium	2	108
6-6-100.....	High-magnesium	2	75
	High-calcium	3	170
	High-magnesium	3	128
Zinc-lime.....	High-calcium	2	145
8-8-100.....	High-magnesium	2	237
Iron-lime.....	High-calcium	2	115
8-8-100.....	High-magnesium	2	89
Zinc oxide-lime.....	High-calcium	2	227
1½-4-100.....			
Manganese sulphate.....	High-calcium	2	246
Lime.....			
4-4-100.....			
Zinc sulphate.....		2	534
4-100.....			
Check. No arsenical or corrective...			82
Check. Lead arsenate only.....		2	309

caused less defoliation than the zinc sulphate high-magnesium lime mixture, and less injury occurred on the plot receiving the 4-4-100 and the 6-6-100 than on the 8-8-100. The trees receiving the 8-8-100 zinc sulphate high magnesium-lime mixture showed the greatest leaf fall when 2 pounds of lead arsenate were used. The increased defoliation, however, may be partly due to drought injury.

Where 3 pounds of lead arsenate were used with a 6-6-100 zinc-lime and iron-lime mixture, more defoliation occurred than where 2 pounds were used. This would indicate that the correctives are not satisfactory where applications of lead arsenate greater than 2 pounds to 100 gallons of water are applied. Zinc oxide, high-calcium lime, 1½-4-100 and manganese sulphate, high-calcium lime 4-4-100 were also tried. These mixtures caused more injury than the zinc sulphate and iron



FIG. 1. Effect of high-calcium and high-magnesium lime bordeaux on defoliation. Photographed September 25, 1936.

The branch on the left was sprayed with a 4-6-100 high-magnesium lime-bordeaux, the branch on the right was 4-6-100 high-calcium lime bordeaux.

sulphate mixtures. Zinc sulphate used without lime caused serious defoliation.

SUMMARY

High-magnesium lime bordeaux appears to contain copper in a more stable form, to cause less defoliation and to have a less dwarfing effect on Montmorency cherries than high-calcium lime bordeaux during a year of low rainfall. The concentration of both high-magnesium lime and high-calcium lime bordeaux is seen to influence growth of shoots and trunks, size of fruit and per cent solids in fruit; the lower concentration having the least dwarfing effect. All the zinc sulphate and iron sulphate lime mixtures gave satisfactory control of arsenical injury on peach. The best control was obtained on the plots sprayed with 6-6-100 and 8-8-100 high magnesium-lime iron sulphate mixture. The high-calcium lime zinc sulphate mixture caused less defoliation than the high-magnesium lime zinc sulphate mixture. Zinc oxide and manganese sulphate in combination with high-calcium lime were unsatisfactory. Zinc sulphate used without lime in combination with lead arsenate caused serious defoliation.

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A Preliminary Report on Asphalt Emulsions Used in Grafting

By H. A. CARDINELL, *Michigan State College, E. Lansing, Mich.*

ABSTRACT

The material presented in this paper is to be published from the Michigan State College.

THROUGHOUT the long history of hand wax formulas, followed by the increasing use of the brush wax method, all naturally led to a search for a cheap liquid preparation that could be applied cold with a brush. For some years investigators have been testing certain water emulsified asphalt preparations.

In 1930 the late James A. Neilson of the Michigan Experiment Station became interested in these new products and used a great number. In 1935 the writer compared several products in a limited way and plans were laid to make an extensive trial in 1936.

In one block of young apple trees, 1,741 cions were placed, on which were compared 18 different mixtures. Ten were modifications of brush wax formulas and eight were asphaltic preparations, all commercial products on the market. All cions were set as cleft grafts. All cion setting and coating was performed by the author, and no support was given to the cions other than the "wax".

The average of four grafting wax formulas using resin as a base resulted in 94 per cent live cions. The average of four formulas using abietic acid as a base resulted in 85 per cent live cions, and the average of six asphalt emulsions resulted in 88 per cent of the cions living. All of these results would satisfy the average tree grafter, especially during such a dry season as 1936.

The standard black brush wax as used in Michigan is made with resin, 5 pounds; beeswax, 1 pound; raw linseed oil, $\frac{1}{4}$ pint; and lamp-black, $\frac{1}{2}$ pound.

It is interesting to note that this formula was used as a "gold" standard and replicated throughout the trials, with the result that over one-sixth of all cions set were protected with this formula. This resulted in 88 per cent live cions, not conspicuously better than the others since the average of the 16 "wax" formulas was 89 per cent, and this includes the favored No. 1 formula.

On the basis of cions living at the close of the first season, of the first ten ranking compounds used as grafting wax, six were brush wax mixtures and four were water emulsified asphalts.

Lanolin as a Wound Dressing for Trees

By G. M. SHEAR, *Virginia Experiment Station, Blacksburg, Va.*

DURING the spring of 1936, lanolin and lanolin indole acetic acid were applied to the upper ends of apple cuttings. It was observed that the treated ends of these cuttings callused readily; the most growth occurring where the lanolin indole acetic acid mixtures were used. The possibility of these materials being used as wound dressings on trees was suggested. Experiments to test these materials as wound dressings were begun during the latter part of April, 1936.

In the past, most wound dressings have been developed with a view toward preventing the entrance of wood rotting fungi which is all right in theory but has not worked very satisfactorily from a practical standpoint. Most wound dressings are ineffective after the first season and subsequent treatments are rarely made. Practically all of these antiseptic materials are toxic to the living plant cells with which they come in contact and until most of their fungicidal value is lost the healing of the wound is retarded; thus more harm than good may result from their use. Neilson mentions a water soluble asphaltic emulsion as being one of the newest and most satisfactory wound dressings which appears to cause little damage. Collins says that with the exception of shellac, healing is more rapid when the wound is not treated. Marshall, in his work on the healing of wounds on forest trees, found little or no difference in those treated with shellac and those that were untreated when the cuts were made in the spring, while those made in the fall healed more rapidly when treated with shellac.

METHODS AND MATERIALS

The treatments included in these tests were hydrous lanolin U.S.P., indole acetic acid, white lead paint, and asphalt. The indole acetic acid was dissolved in the lanolin at the rate of 1 part to 200 parts of lanolin. Treatments were made within an hour of the time the branches were removed. The cuts were made at various places in the trees, care being taken to leave no stubs. Sugar maple, linden, seedling, and Grimes Golden apple trees were used. The growth of callus was determined by means of vernier calipers, measurements being taken on each side of the wounds.

DISCUSSION AND RESULTS

Lanolin is a wax of about the same consistency of petroleum jelly. It is obtained from the washing of wool, its principal component being cholesterol. One of its most unique features is that it mixes readily with several times its own weight of water. From the data that have been collected, lanolin appears to be non-toxic to both animals and plants. Gudjonsson found that wool fat from Iceland contained appreciable amounts of vitamin A, and it is possible that it may contain other materials that have a stimulative effect on living tissue. It has been used for some time as the base for salves and has been regarded as having slight antiseptic properties. Its use on plants as far as can be

ascertained from available literature has been limited to its use as a medium for the application of plant hormones and other growth promoting substances chiefly on cuttings and herbaceous plants.

Indole acetic acid or hetero-auxin is a growth promoting substance or hormone that has been experimented with quite extensively during the past few years. In using this material with lanolin on apple cuttings a mixture of 1 to 100 gave the most callus formation. Since the surface to be covered on the tree wounds was much larger a 1 to 200 mixture was used.

The sugar maple and linden trees used were large trees that had just been transplanted and they required considerable pruning. On these trees the cuts varied in size from one to several inches in diameter and three different treatments were used, namely, asphalt, lanolin, and lanolin indole acetic acid. Due to the weakened condition of the trees insufficient healing occurred for comparative results to be obtained.

On April 28, 1936, wounds were treated on eight Grimes Golden apple trees, in a young commercial orchard, near Blacksburg, Virginia. The branches were removed from the lower portion of the trees and averaged $1\frac{1}{4}$ to $1\frac{1}{2}$ inches in diameter. The treatment of these cuts included white lead paint, lanolin, lanolin indole acetic acid, and untreated wounds.

On May 5, 1936, a number of branches were removed from a mature apple tree of unknown variety growing near the experiment station building. This tree had not been pruned for a number of years and contained many branches about $1\frac{1}{2}$ inches in diameter. Branches were removed from all portions of this tree. In this instance the treatments consisted of lanolin, lanolin indole acetic acid and untreated wounds.

Within 3 weeks after these treatments were made the growth of callus was noticeably better on wounds treated with plain lanolin. The results of measurements taken after 3 and 5 months are shown in Table I. It will be seen that the lanolin-treated wounds produced the greatest amount of callus in both series of treatments and at both dates of measuring. In one series wounds treated with lanolin indole acetic were intermediate to wounds treated with lanolin and to untreated

TABLE I—GROWTH OF CALLUS ON APPLE TREE WOUNDS

Treatment	Number of Wounds	Percentage of Diameter Callused Over	
		3 Months	5 Months
<i>Grimes Golden</i>			
Paint	14	20	24
Untreated	8	23	30
Lanolin—IAA	13	24	28
Lanolin	13	30	38
<i>Variety Unknown</i>			
Untreated	10	18	24
Lanolin—IAA	15	21	28
Lanolin	10	31	35

wounds, while in the other series there was no significant difference between untreated wounds and wounds treated with these materials. The wounds treated with paint gave the poorest growth in the series in which they were included. The callus tissue covered approximately one-fifth more area where plain lanolin was used than it did on untreated wounds.

Most, if not all, of the beneficial effect of the lanolin was due to its preventing the drying of the cambium and young callus. Its consistency is such that a film is maintained over the growing callus thus permitting unimpeded growth. On wounds that were exposed to the sun the lanolin had all been absorbed by the wood, by October. Shaded wounds were still covered by a film of lanolin.

The indole acetic acid, while used in a lower concentration than that which gave the most callus on cuttings, did not produce a similar stimulation when applied to wounds on trees. Apparently the concentration used was too great to produce a stimulation of callus. It would appear reasonable to expect more growth with lanolin indole acetic acid than with lanolin alone, provided the proper amount of this hormone were used. It is planned to continue this work using lanolin with growth promoting substances in various proportions, also mixing lanolin with other materials to raise its melting point and yet maintain its plasticity. By these methods the beneficial effects of lanolin as a wound dressing should be enhanced.

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Propagating Citrus by Twig Grafting

By F. F. HALMA and E. R. EGGERS, *University of California, Los Angeles, Calif.*

IN a report (1) on the propagation of citrus by means of cuttings, attention was also drawn to a method of propagation by which two stem cuttings of the desired varieties are tongue-grafted together and then rooted like an ordinary cutting (Fig. 1). The success of the method depends upon the same conditions as those which are necessary for the rooting of citrus cuttings, namely, using twigs with healthy mature leaves taken from trees in vigorous condition, maintenance of high humidity in the propagating frame by frequently sprinkling the cuttings to keep the leaves turgid and maintenance of a sand temperature of about 75 degrees F. Twig grafts representing commercial combinations were planted in the orchard in 1930 and they have thus far grown normally. There is however an interesting scion effect on the root-system which is absent in budded trees (2). One advantage of the twig grafts lies in the fact that plants suitable for experimental purposes can be obtained in about 3 months whereas at least 2 years are required to grow budded trees to the same stage. Moreover the rootstock of the latter is a seedling which, in critical experiments, is an objectionable feature.

There is an increasing interest among citrus growers in double-worked trees, that is, one in which the scion and stock is separated by an "intermediate" or commonly called "Sandwich". Claims are sometimes made that a lemon tree, for example, composed of a sour orange rootstock and a sweet orange "intermediate" is superior to one directly budded onto the sour orange. Such claims, however, are not based on experimental evidence.

The complexity of the problem can be visualized from the fact that five species of citrus are in common use in Southern California either as rootstocks or scions.

To grow even a few of the triple combinations for experimental purposes, requires considerable space and time. The twig graft method seems to meet this problem of plant material. During the past year combinations of the Eureka lemon, sweet and sour orange were rooted and



FIG. 1. Twig graft before and after rooting. The arrow points to the graft union.

planted in the nursery. In all cases the lemon served as the scion and the other two species either as rootstock or as the intermediate. Due to limitation of space only about 50 grafts were made of which 80 per cent rooted. In triple grafts the twig portions must be made shorter than in the double grafts; otherwise the plant becomes too long and



FIG. 2. Rooted twig grafts composed of two, three, and four twigs. Arrows point to the graft union.

difficult to handle. The "intermediate" can be made very short as it serves only as an interruption between stock and scion. With the exception of the number of components the triple grafts are similar to twig grafts and require the same care. A preliminary test was made on grafting together four twigs. In order to insure compatibility, all twigs were taken from one Eureka lemon tree. These rooted satisfactorily as seen from Fig. 2 which shows double and triple grafts for comparison.

Thus, attention is drawn to a further development of the "twig graft" method which makes it possible to graft together three different species and then induce the one serving as the rootstock to root in sand like an ordinary citrus cutting. The usefulness as plant material for critical investigations concerning scion-rootstock relationship is stressed.

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Rooting of Papaya Cuttings

By HAMILTON P. TRAUB and L. C. MARSHALL, U. S. Department of Agriculture, Washington, D. C.

ALTHOUGH progress is being made in developing pure lines in the dioecious type of *Carica papaya* which will make it easy to propagate this crop by means of seeds, there is still need for a workable method of propagating the papaya asexually. This is especially true when valuable heterozygous parent clons are to be preserved and increased for use in breeding experiments. The graftage methods described (3, 5, 10) have not proved practicable under the usual conditions under which this fruit crop is grown. Pope (6) mentions cuttage experiments but concludes that the results "did not indicate that the propagation of the papaya by means of cuttings is of much practical value." Cheema (1) draws a similar conclusion.

The earlier attempts of Traub and Auchter (8) to propagate the papaya by rooting cuttings in sawdust, sand, and mixtures of sand and peat, under ordinary lath-greenhouse conditions in Florida proved ineffective. However, it was noticed that when lots of cuttings were covered with bell jars, they lived on for 18 months or more but developed no roots, and made only very feeble top growth.

Further experiments were undertaken in which the cuttings were housed in a solar propagating frame in Florida, and in an air-conditioned greenhouse in California. The work was planned primarily to determine the effect of relatively higher temperature of the rooting medium as contrasted with the air temperature above—a condition commonly referred to as application of "bottom heat"—on the rooting response of papaya cuttings. The effect of indoleacetic acid (9) on rooting response was also considered in a preliminary way.

MATERIALS AND METHODS

Practically all of the work carried out to date concerns *C. papaya*. A limited number of cuttings of *C. quercifolia* and *C. dodecaphylla* have been included. The work on these and other species of *Carica* will be reported on later when more extensive data have been accumulated.

The strains used in the Florida experiments were selections of the dioecious type within sib-pollinated lines in the second generation. The material was fairly homozygous for the chief horticultural characters. In California open-pollinated strains were used.

Four types of cuttings were used in these experiments, (a) the entire branch including the natural swelling at the proximal (basal) end; (b) distal cuttings from branches, (c) the median portion, or portion between the distal and proximal portions, and (d) the proximal portion which is next to the trunk including the natural swelling at the basal end of the cutting. These four types were varied as to diameter and length, and also as to place of cutting at node or internode for distal and median types of cuttings.

Various sizes of cuttings were included, from $\frac{1}{4}$ inch to $2\frac{1}{2}$ inches or more in diameter and 3 inches to 3 feet in length. The diameter

of the cuttings for most of the work averaged 0.67 ± 0.035 inches (C. V. 9.17) for the tip cuttings, and 1.88 ± 0.039 inches (C. V. 4.52) for the cuttings taken below the tip. The length of most of the cuttings averaged 5.5 inches which was the size most easily handled in the solar frame.

In the solar propagation frame a mixture of Lake Eustis sand (coarse) and granulated peat in equal parts to a depth of 6 inches, and in the air conditioned greenhouse a medium grade of river sand to a depth of 6 inches, were utilized as rooting media.

In the solar propagation frame (7) the average temperature and humidity fluctuated as follows: for the 8-hour period 8 a. m. to 4 p. m. the soil temperature rose from 81 degrees F to 92 degrees F with the air temperature from 1 degrees F (at 8 a. m.) to 4 degrees F (at 4 p. m.) lower than the soil temperature, and the average relative humidity ranged from 92 per cent at 8 a. m. to a low of 68 per cent at 2 p. m. and 75 per cent at 4 p. m.; for the 16-hour period 4 p. m. to 8 a. m. the soil temperature fell from 92 degrees F at 4 p. m. to 81 degrees F at 8 a. m. with the air temperature from 4 degrees F lower at 4 p. m. to 1 degree F lower at 8 a. m., and the average relative humidity ranged from 75 per cent at 4 p. m. to 92 per cent between 8 p. m. and 8 a. m.

In the air conditioned greenhouse the soil temperature was maintained at 85 degrees F by means of an electrically heated cable imbedded in the rooting medium. A preliminary test had shown that 95 degrees F caused most of the cuttings to rot. The air temperature ranged from 75 to 77 degrees F during the day, and 66 to 68 degrees F at night; the relative humidity was maintained at 85 to 90 per cent during the day and 90 to 95 per cent at night.

Synthetic indole-3-acetic acid was applied to cuttings either by the lanolin method of Laibach (4) in a concentration of 1:500; or as a 1:10,000 water solution according to the method developed by Cooper (2). The latter gave best results.

The propagation beds were heavily shaded in all cases. The approximate light intensity in the air conditioned greenhouse on the average was between 100 and 200 foot candles as indicated by a Weston photronic cell, and were of course subject to the daily and hourly fluctuations of light in the greenhouse.

RESULTS

The application of "bottom heat" under the conditions of these experiments was markedly effective in stimulating rooting response in papaya cuttings, and a large number of cuttings have been successfully rooted by this method.

The results from three typical experiments in two different years in the solar propagation frame are cited here. Cuttings, 20 in number—half distal and half median—placed in the solar frame on July 15, 1935, gave 60 per cent rooted cuttings for the distal type and 70 per cent for the median type by September 25, and 90 per cent and 80 per cent respectively at the end of the experiment some months later. Cuttings, 40 in number (10 distal, 10 median cut at node, 10 median cut at internode, and 10 proximal), placed in the solar frame on April

28, 1936, gave 80 per cent, 70 per cent, 70 per cent, and 100 per cent rooted cuttings, respectively, by May 23. Small branch cuttings, 20 in number, placed in the solar frame July 27, 1936, gave 95 per cent rooted cuttings by August 26; and 10 large branch cuttings 14 inches to 30 inches in length placed in the solar frame at the same time gave 100 per cent rooted cuttings at the end of the same period.

In the air conditioned greenhouse cuttings placed in the rooting medium September 1, 1936, 30 with base soaked for 42 hours in 1-10,000 solution of B-indole-acetic acid, and 36 controls with base soaked for 42 hours in water, gave 50 per cent rooted cuttings for those treated against 27.7 per cent for the controls. The hormone treated cuttings averaged 23 roots as against an average of 12 roots for the controls.

Apparently no significant differences due to varieties and the sex forms of the dioecious type, pistillate and staminate, were observed.

Some differences have been observed with regard to time required for the rooting response. Under the conditions of the experiments in the solar frame in Florida this usually requires about 1 month although rooting may begin in 2 to 3 weeks. In some cases a much longer time was required.

Entire branches with the solid proximal (basal) swelling attached furnish the best cutting material, followed by proximal cuttings with solid basal swelling attached, and distal cuttings. Median cuttings are more difficult to handle although under the conditions of these experiments they gave fair results.

Entire branch cuttings of various sizes (5 inches to 3 feet in length) have been used and all have given excellent results. However, large cuttings are difficult to accommodate in a solar frame. In the case of the other types of cuttings extremes of very small and large diameter have given poor results. The best size for convenient handling seems to range from about $\frac{1}{2}$ inch to 1 inch in diameter.

It has been reported (6) that rooted papaya cuttings are difficult to transplant but this has not been the experience in this work. When roots are sufficiently developed and the growing conditions are favorable the loss in transplanting has been nil. However during cool, damp weather some considerable losses are usually experienced. Fall rooted plants should be transferred to 6 x 6 x 9 inch plant boxes and wintered on the south side of a building and transplanted in March or April.

It has been reported (6) that median and proximal cuttings give rise to plants with crooked stems. However, plants may be set with the "crook", or asymmetrical portion, below the ground surface and then there is no question of a "crooked" stem, but plants set with "crooked" stems above the ground surface have in every case straightened out completely within 3 months.

Enough time has elapsed to bring many plants into fruiting. They have behaved in every way like seedlings excepting that they came into bearing earlier and some even began to flower in the solar frame.

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The Location of the Line of Union in a Cleft Graft¹

By F. C. BRADFORD, *Michigan State College, E. Lansing, Mich.*

SOME of the early discussions of effect of stock on cion adduced, as evidence of such effect, cases in which a shoot arising on the cion in close proximity to the stock bore fruit like that of the stock. The accompanying figure (Fig. 1) shows how some, at least, of these reports probably arose. It depicts a cleft graft union of two Woodmansee cions on Longfield. The adventitious shoot growing downward (on the left) arises above the point where the Longfield limb was cut off when the Woodmansee cions were inserted, but it bears Longfield apples. Instead, however, of showing the effect of stock on cion, it simply illustrates the extent to which the callus from the stock grows over the stub in a well-made cleft graft. The actual course of the line of union (indicated by the dotted line) proceeds from the cleft on the right diagonally to the point marked A and then diagonally to the cleft on the other side. The line where the old bark was sawed marks the line of union at no point except at the corners of the clefts.



FIG. 1

¹Journal Article No. 273 (n.s.) from the Michigan Agricultural Experiment Station.

A Third Experience in Producing Stock Effects With Ring Grafts

By R. H. ROBERTS, *University of Wisconsin, Madison, Wisc.*

FOR a third time stock effects upon the growth of nursery trees were secured by grafting a ring of bark upon yearling trees (1, 2). In previous years the growth of the trees was expressed as the ratio of the previous and current season lengths. This was done to minimize the error which would arise if the growths were averaged. As large trees make more growth in a succeeding season than small trees of the same age, the effect of a cultural treatment, as ring grafting, is more accurately determined by comparing the two seasons' increments. As the tops of the trees were eaten off during the winter of 1935-36 by rabbits working on the crust of a deep snow, the data of 1936 are given as the ratio of the length in 1936 in centimeters to the diameter in 1935 in millimeters. Table 1 gives the data on 1-year trees. Similar responses were secured when rings of bark were placed upon 2-year old nursery trees (cutbacks).

As in previous years, there was a difference in the effect of the different rings. Also, the effect of a ring upon the amount of growth varied with the stock and scion combination. A ring which gave a good growth on one variety may result in a poor growth when on another stem variety. This is a similar response to that secured from double-working (3).

To obtain information upon the question of where the xylem under a ring originates, bark from the red-wooded and red-barked Hopa Crab was used for rings. The new xylem under Hopa rings had a red color, indicating it arose from the cambium of the bark. The stem diameter through a ring was less than that above or below the ring in the case of Winesap (see diagram, A, B). The grafts were made after the bark would slip and at that time some new xylem tissue had formed. In case the Crab bark did not entirely surround the stem, a gap of tissue from the stock formed between the areas of red-colored xylem (diagram, C).

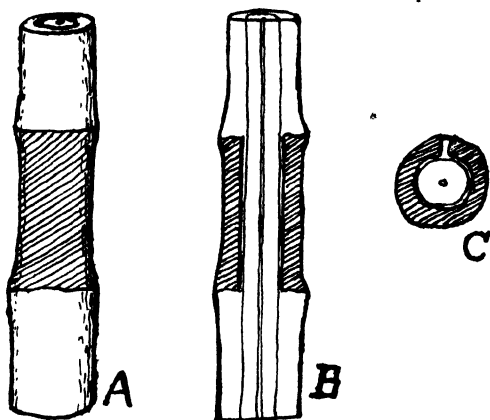


FIG. 1. Ring graft of Hopa Crab on yearling Winesap apple tree. (A) General view of ring graft; (B) Longitudinal section; (C) Cross section.

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TABLE I—RATIO OF GROWTH IN 1936 IN CENTIMETERS TO THE DIAMETER OF GROWTH IN 1935 IN MILLIMETERS

Ring	Stem Variety								
	Whitney	Tetofsky	York	Winesap	Snow	McIntosh	Yellow Siberian	Yellow Transparent	Wealthy
Self . . .	8.7 ± .29	7.1 ± .19	10.5 ± .37	12.2 ± .67	9.7 ± .42	13.8 ± .41	—	11.8 ± .41	11.1 ± .55
Malling 9 . . .	8.0 ± .22	5.1 ± .26	11.2 ± .18	12.3 ± .37	10.3 ± .57	13.5 ± .24	—	—	—
Malling 12 . . .	9.0 ± .23	7.6 ± .25	11.3 ± .34	11.2 ± .63	10.4 ± .33	12.4 ± .37	—	—	—
Snow	—	6.7 ± .31	—	11.1 ± .37	—	—	9.1 ± .29	10.5 ± .42	—
York	7.7 ± .44	8.0 ± .20	—	—	10.7 ± .34	14.4 ± .70	—	—	—
Wealthy	—	—	9.5 ± .04	11.1 ± .38	12.0 ± .62	12.4 ± .57	9.3 ± .45	12.2 ± .47	—
Hopa	9.6 ± .24	7.5 ± .19	—	16.2 ± .54	13.2 ± .42	13.2 ± .31	—	—	—
Inverted ring .	3.8 ± .29	—	5.9 ± .71	—	—	2.7 ± .24	—	7.1 ± 1.01	4.1 ± .28
Girdled	—	—	—	4.5 ± .43	—	4.5 ± .29	—	—	5.7 ± .29
Ungrafted . . .	12.0 ± 1.08	9.0 ± .27	11.2 ± .48	15.4 ± .51	12.8 ± .51	15.1 ± .53	11.3 ± .12	14.7 ± .65	15.0 ± 1.09

The Relation Between the Size of Apple Seedling Rootstock and Size of Orchard Tree¹

By KARL D. BRASE and H. B. TUKEY, *New York State Experiment Station, Geneva, N. Y.*

AMERICAN orchard trees are propagated almost entirely upon rootstocks raised from seed. Theoretically, such rootstocks might be expected to show considerable variation which, in turn, might be responsible for some of the variation seen in orchard trees. Accordingly, nurserymen as well as fruit-growers have often asked: "Do large seedling rootstocks produce the larger orchard trees?" "Is the genetic make-up of the rootstock responsible for the growth and behavior of orchard trees?"

In an earlier publication (2) special attention was paid to the effect of size of rootstock on the growth of the budling and of the 2-year-old tree in the nursery, and it was shown that in a population of 18,000 individuals there was, first, a very high correlation between the size of the 1-year nursery tree and the size of the 2-year nursery tree; second, a smaller yet significant correlation between the after-budding size of the seedling and the size of 1-year and 2-year nursery trees; and lastly, no relation between the size of the seedling at planting and the size of 1-year and 2-year nursery trees. The present paper is a continuation of that work, and presents data on the influence of size of the rootstock and of the nursery tree on the growth of orchard tree when planted out.

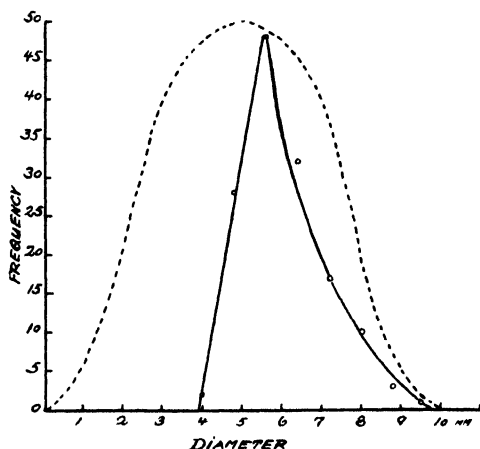


FIG. 1. Distribution of seedling rootstocks used in the experiment according to size (solid line) as contrasted with the normal curve of infinite numbers, showing the uniformity of material.

MATERIALS AND METHODS

For the experiment, 270, 2-year old Early McIntosh trees, comprising two nursery rows, were selected. These had been budded on imported French Crab seedlings and grown on the Station grounds. The seedling rootstocks when received were well graded as to size, as shown in Fig. 1, and the subsequent growth in the nursery of both rootstocks and budded trees was fully equal, if not superior, to commercial blocks of apple trees in adjacent commercial nurseries.

¹Journal Paper No. 187 of the N. Y. State Agricultural Experiment Station.

Before digging, each tree was tagged with a number corresponding to the original nursery number. No sorting or grading was done and no undesirable trees eliminated, each tree being planted in the orchard according to its numerical order in the nursery row, the entire plan of the experiment being to emphasize any variability that might be present in the trees. In accepted nursery practice the smaller size trees would have been separated, if not discarded in grading.

The trees were planted 6 feet apart in the row, in rows 8 feet apart, on a uniform piece of Ontario stony loam, a soil considered high in fertility. Such close planting did not interfere with the experiment, since a retransplanting of every other tree after 3 years in the orchard was contemplated, and later carried out. By retransplanting, it was hoped to determine whether superiority of some trees was due to the genetic constitution of the seedling rootstock or to the environment or cultural treatment.

The planting was kept in clean cultivation for 3 years, after which a legume cover crop was grown between the rows. No pruning was done except for a light thinning out during the sixth year in the orchard. Proper disease and pest control was practiced throughout the period, and the trees, with the exception of those retransplanted a second time after they had been growing for 3 years in the orchard, made very vigorous growth. Retransplanting, of course, checked the growth considerably during the following two seasons, but after this a normal growth was gradually reestablished. All in all, the conditions under which the trees were grown were such as would be considered very satisfactory from both the nursery and orchard standpoint, and such as would provide opportunity for both genetic and environmental factors to assert themselves.

Trunk diameter was used as a measure of tree growth (3). This is a measure of total growth, rather than growth increase for each individual growing season. In some instances, therefore, a large tree may appear still larger than a smaller one although the actual increase in growth in that one season may have been greater with the smaller tree. Yet, since we are mostly interested in showing the general trend of tree growth over a period of years, total trunk diameter measurement should be satisfactory.

Measurements were taken by caliper to the nearest millimeter exactly 12 inches above the union, each year during the dormant period. The figures obtained for each tree were entered on cards, providing very helpful means of tabulating the accumulated data and arranging the correlation tables. The coefficient of correlation (r)² from grouped data was determined by the unity step method (4). The standard error (δr)³ for the coefficient of correlation has been used throughout.

In all, 52 correlations were made of which forty-five deal with seedling rootstock, budling, 2-year nursery tree, and the resulting orchard

$$r = \frac{\sum P}{N} - (cx cy)$$

$$\delta r = \delta r = \frac{1-r^2}{\sqrt{N}}$$

tree from the first to the sixth year in the orchard; and the remaining seven deal with retransplanted orchard trees, which were first grown for 3 years in the orchard and then retransplanted to a new orchard location. The following designations have been used throughout in tables and graphs:

- I = Seedling rootstock at planting.
- II = Seedling rootstock at the end of the first season's growth.
- III = Budling (1-year old budded tree).
- IV = Two-year nursery tree.
- V = First year in the orchard.
- VI = Second year in the orchard.
- VII = Third year in the orchard.
- VIII = Fourth year in the orchard.
- IX = Fifth year in the orchard.
- X = Sixth year in the orchard.
- VIIIa = First year of retransplanted 3-year old orchard tree.
- IXa = Second year of retransplanted 3-year old orchard tree.
- Xa = Third year of retransplanted 3-year old orchard tree.

RESULTS

The correlations between the size of the rootstocks and the size of the nursery and orchard trees are presented in Table I. Further, correlations are given between the size any one year and the size any other year, extending over a period of 10 years from the seedling to the 6-year-old orchard tree. The data are plotted in Fig. 2, which emphasizes the trend and relationship much better than a study of the

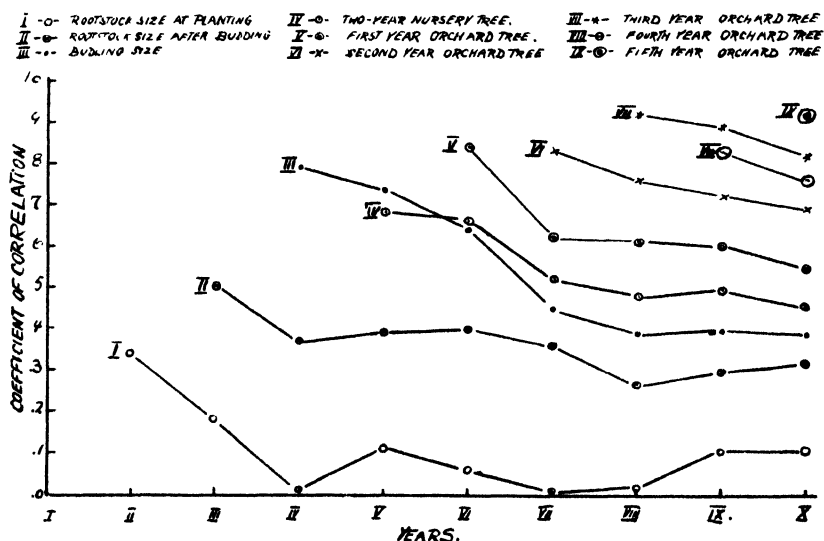


FIG. 2. Correlations between the size of rootstock and tree any one year and the size any other year, extending over a 10-year period from the seedling to the 6-year-old orchard tree (Table I).

TABLE I.—CORRELATION IN EARLY MCINTOSH TREES FROM SEEDLING ROOTSTOCK TO 6-YEAR-OLD ORCHARD TREE (FIG. 1)

	Seedling Rootstock at Planting I 1	Seedling Rootstock After Bud- ding II 2	Budling III 3	Two-Year Nursery Tree IV 4	1st Year Orchard Tree V 5	2nd Year Orchard Tree VI 6	3rd Year Orchard Tree VII 7	4th Year Orchard Tree VIII 8	5th Year Orchard Tree IX 9
Seedling rootstock after Budling II	$r = .3408$ $\pm .0747$								
Budling III	$r = .1976^*$ $\pm .0812$	.5024 $\pm .0632$							
2-year nursery tree IV	$r = .0152^*$ $\pm .0843$	.3479 $\pm .0726$	.7944 $\pm .0312$						
1st year orchard tree V	$r = .1176^*$ $\pm .0853$	.3902 $\pm .0716$	.7480 $\pm .0372$	.7008 $\pm .0430$					
2nd year orchard tree VI	$r = .0619^*$ $\pm .0842$	.4035 $\pm .0708$	.6446 $\pm .0494$	.6627 $\pm .0474$	.8446 $\pm .0242$				
3rd year orchard tree VII	$r = .0127^*$ $\pm .0845$	.3652 $\pm .0732$	.4589 $\pm .0667$	.5282 $\pm .0609$	.6226 $\pm .0518$	.8343 $\pm .0257$			
4th year orchard tree VIII	$r = .0232^*$ $\pm .0832$	.2738 $\pm .0782$	.3994 $\pm .0709$	.4874 $\pm .0649$	.6197 $\pm .0521$	.7616 $\pm .0355$	.9285 $\pm .0117$		
5th year orchard tree IX	$r = .1145^*$ $\pm .0837$	.3023 $\pm .0668$	.4008 $\pm .0709$	.4975 $\pm .0636$	.6018 $\pm .0539$	.7295 $\pm .0376$	.8922 $\pm .0172$	.8376 $\pm .0252$	
6th year orchard tree X	$r = .1165^*$ $\pm .0834$	.3218 $\pm .0758$	.3940 $\pm .0714$	.4675 $\pm .0660$	.5520 $\pm .0588$	.6954 $\pm .0436$	.8295 $\pm .0264$	.7621 $\pm .0354$	.9265 $\pm .0120$

*Not significant.

table alone. Table II and Fig. 3 present the correlations for the trees retransplanted after 3 years' growth in the orchard. A few of the more significant points are mentioned in the paragraphs which follow.

1. *Size of Rootstock at Planting and Subsequent Tree Growth:*—The correlation coefficients given in Table I, column 1 show at once that there is no relationship between the size of the rootstock when planted and the future growth of the budded tree either in the nursery row or in the orchard. The values for (r) are very low, and since they are not greater than three times the standard error are considered mathematically not significant. The only apparently significant relation that exists is between the lining-out size and the growth in the nursery up to after-budding size, although this may be due more to the method of taking measurements (total diameter) than to actual increase. Large seedlings, although possibly increasing less than smaller ones, may have remained larger. The coefficient of correlation of .3408 is small and accounts for approximately only 11 per cent $[(.3408)^2 = .1161]$ of the total related variation of 1.00.

2. *After-budding Size of Rootstock and Subsequent Tree Growth:*—The figures in Table I, column 2, show a fairly strong relationship between the total growth made by the rootstock during the first growing season and the size of the budling obtained. This relationship becomes less with the 2-year-old budded tree but remains more or less constant during the following years in the orchard.

3. *Size of Budling and Subsequent Tree Growth:*—The size of the budling (column 3) and the size of the 2-year-old nursery tree show a strong correlation. Likewise, there is a high correlation between the size of the budling and the size of the tree for the first 2 years in the orchard. This indicates that the largest budling will remain the largest tree for the next 3 years. After this period a fairly constant but rather low coefficient of correlation is again maintained.

4. *Size of 2-Year-Old Nursery Tree and Subsequent Tree Growth:*—The correlation between the size of the 2-year nursery tree (column 4) and the size of the tree in successive years in the orchard is similar to that for the budling, yet still greater. The largest 2-year trees from the nursery are still the largest orchard trees after 6 years in the orchard, although the correlation becomes less with each season's growth. The very high correlation between the size of the 2-year nursery tree and the size of tree after 1 year in the orchard is probably due to a check in growth following transplanting, so that little increase in size occurred during the first year in the orchard.

5. *Yearly Size of Orchard Trees and Subsequent Tree Growth:*—The coefficient of correlation is very high between the size of tree after the first year in the orchard and the size of the tree thereafter (column 5). The correlation is highest for the first year and becomes somewhat lower with each successive year.

Similarly, the correlation remains very high and quite constant for the size of the tree in any other year and the size of tree thereafter. This indicates that the trees, having reached a certain size or having attained a certain balance in their new establishment, increase at a very uniform rate thereafter, regardless of former size.

6. *Size of Budling and Growth of Retransplanted Trees:*—The results following retransplanting of the trees to a new orchard location after 3 years' growth in the orchard are shown in Table II and represented graphically in Fig. 3.

TABLE II—CORRELATION IN EARLY MCINTOSH TREES FROM SEEDLING ROOTSTOCK TO 6-YEAR-OLD ORCHARD TREE. RETRANSPLANTED TREES. (FIG. 3)

	Budling III 1	3rd Year Orchard Tree (at Retransplanting) VII 2
3rd year orchard tree VII	$r = .5212$ $\pm .0644$	— —
Orchard tree first year in new location VIIIa	$r = .4899$ $\pm .0672$	.8976 $\pm .0172$
2nd year in new location IXa	$r = .3829$ $\pm .0754$	.5591 $\pm .0610$
3rd year in new location Xa	$r = .2301$ $\pm .0837$ (not significant)	.3414 $\pm .0784$

sented graphically in Fig. 2. The values for the coefficients of correlation in column 1, show a trend very similar to that for the 2-year nursery tree when correlated with the 6 years' growth of trees in the orchard. The coefficient of correlation for the first year after retransplanting is nearly as large as that for the third year in the orchard. Here again this is probably due to the check in growth following transplanting. The next 2 years in the new location show a rapidly decreasing coefficient of correlation. The third year after retransplanting this coefficient is no longer mathematically significant, indicating that some small trees have made greater gains in trunk diameter than some large ones. This means that the transplanting operation and the new location have had a greater effect upon subsequent growth than any inherent size factor present in the nursery trees.

7. *Size of 3-Year-Old Orchard Tree and Growth Following Retransplanting:*—Here again a very high coefficient of correlation is shown between size at retransplanting and the size after the first year in the new location. A rapid decrease in the value for the coefficient of correla-

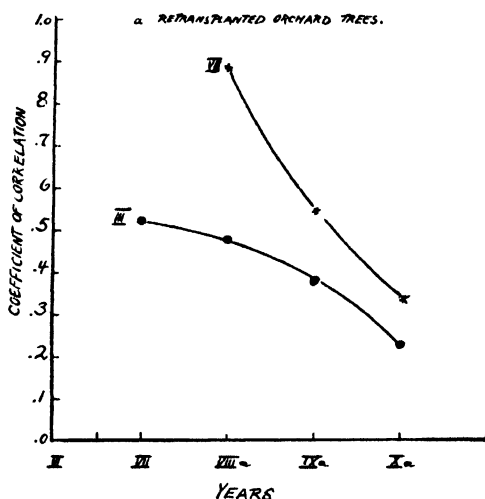


FIG. 3. Correlations with retransplanted trees (Table II). III = Budling size; VII = Third-year orchard trees; a = Retransplanted orchard trees.

tion follows, giving further evidence of the influence of cultural treatment and environment on the growth of the retransplanted tree.

DISCUSSION AND CONCLUSIONS

The data indicate that the original nursery size of the seedling rootstocks used in this experiment has played little if any part in the growth of orchard trees propagated upon them (1). It must be remembered, however, that these seedling rootstocks were of good commercial grade, uniform (Fig. 1), and vigorous. If the genetic constitution of the rootstocks were responsible for the growth made by the trees, different values for the coefficient of correlation should have been secured. For comparison it would be of interest to conduct a similar experiment with trees budded to a vigorous clonal rootstock.

Such operations as digging from the nursery and planting have had a marked influence on the growth of the trees, regardless of any possible inherent vigor of the rootstock. Furthermore, the method of budding, the time of budding, and the condition of the seedling rootstock at time of budding, seem to be important factors which may be expressed in the growth of the resulting tree for a considerable time in the nursery row and for a considerable time after transplanting to the orchard. Retransplanting to a new location after the trees have been once established in an orchard seems to result in an equalization in the growth of the larger and smaller trees and tends still further to overcome or mask any possible inherent vigor of the rootstock.

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An Unusual Leaf Characteristic Which is Useful in Identifying the Virginia Crab Apple Stock¹

By T. J. MANEY and H. H. PLAGGE, *Iowa Agricultural Experiment Station, Ames, Iowa*

THE excellence of the Virginia Crab as a stock for use in the double working of apples, and the interest which is being shown in the variety by growers, makes it imperative that the variety be kept free from mixtures. With this in mind, there has been given in a previous paper² a description of certain tree and leaf characteristics by which it is possible to identify Virginia Crab under ordinary conditions.

At various times it has been suggested that there might be a possibility that a number of different strains of Virginia Crab are being propagated and distributed by nurserymen. During a period of years the writers have had an opportunity to observe the variety over a wide range of territory and under various conditions, but have never noted what might be a closely related strain or type. Where variations have been observed they have been the result of mixtures by one or more of the numerous crab varieties. During the past season a number of nurserymen have submitted samples of Virginia Crab for identification. The true type was easily identified. The mixtures have been mostly Yellow Siberian, *Pyrus baccata*, Hyslop and Whitney.

In the winter of 1936 the writers' attention was called to the problem of a grower who had secured an original supply of the Virginia Crab from three different Iowa nurserymen. A considerable number of nursery trees had been propagated from the original trees. The question then arose in the grower's mind as to whether there might be variant types or mixtures in the various lots. The grower wished to plant and stem graft the trees in the spring of 1936.

It was finally arranged to have samples of the three lots of stock sent to Ames. These were planted in the greenhouse along with trees of the true Virginia Crab type. At the same time there was also growing in the greenhouse a lot of 15 or 20 other apple varieties, included in which were several crabs.

When the Virginia Crab samples came into full leaf, it was easily determined by the usual leaf characteristics that the lots submitted for identification were all of the true Virginia Crab type. However, while examining the leaves at various times, it was noticed that there was a distinct golden colored pubescent-like deposit along the main veins. An examination of this, first under a hand glass and later under a low powered microscope, showed that it was not pubescence, but an accumulation of small, yellow, oval shaped wax globules. None of the other varieties in the house showed a similar leaf characteristic.

The portion of the leaf shown in Fig. 1 shows clearly the nature of these wax bodies, and indicates that a characteristic of this kind is an important single factor in determining the identity of the Virginia Crab. Identification by this characteristic is only possible during the early stages of growth and under greenhouse conditions with temperatures

¹Journal Paper No. J408 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 288.

²Maney, T. J. Three apple stocks especially well adapted to the practice of double working. Proc. Amer. Soc. Hort. Sci., 32: 330-333. 1934.

below 60 to 70 degrees F. Higher temperatures melt the wax and make this method of identification valueless. Ordinary field temperatures have the same effect. However, there is suggested in this obser-

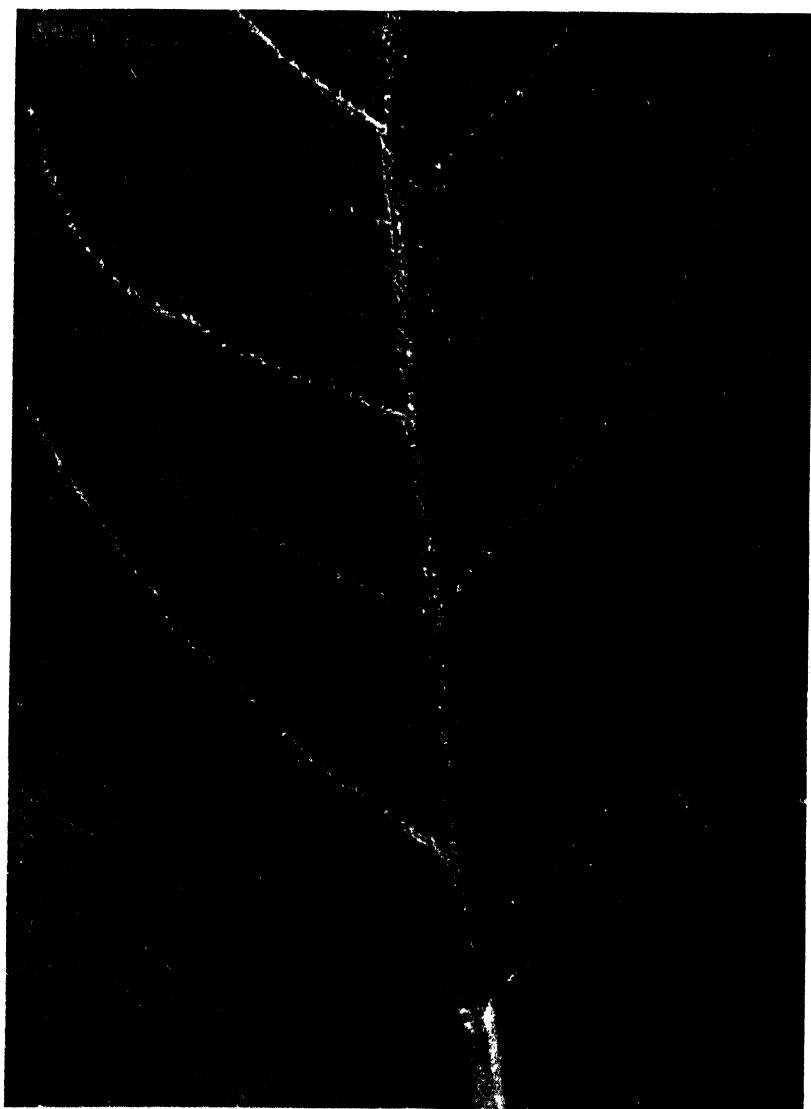


FIG. 1. Distribution of wax globules along main veins of Virginia Crab leaf.

vation the possibility of discovering by careful studies other minute characteristics which may be of considerable value in definitely identifying varieties in all our classes of tree and small fruits.

A Method for Appraising Apple Clonal Stock Material in the Nursery

By F. B. LINCOLN, *University of Maryland, College Park, Md.*

THE hundreds of acres of escaped apple seedlings and indigenous apple species, along with the frequent veteran trees marking the locations of former seedling orchards, are a real challenge to one interested in the biology of the apple (Fig. 1). They should motivate anyone interested in fruit tree stocks, for upon observing these uncultivated trees often thriving under what is considered adverse conditions, one is forced to anticipate that some of them might be suitable for appropriation to pomology as stocks.



FIG. 1. Three seedling apple trees and a large upright specimen of *Malus coronaria*.

Much thought was given to devise a method or program to readily test the potentialities of many of these uncultivated apple trees for use as fruit stocks. The first and most essential feature of a stock is the performance of the combination in which it is a part. Its own individuality, while important, becomes secondary to the complete effect. Therefore an appraisal of the material should be concerned primarily with the growth, or the ability to deposit dry matter, of combinations between these wildlings and the wood valued for fruit production. Any scheme amendable to nursery practice must be short in duration of time and consequently only the juvenile responses of trees can be observed. As stock effects only have relative values, it is necessary to set up an arbi-

trary reference standard. Since the pomologist has not decided on standards or norms for the performance of apple trees, it became necessary to choose a specific combination that these test plants would excel or be inferior to. After much bewilderment two clonal stocks were chosen to become parts in combinations to be used as reference standards. They were: U.S. 600, a French crab derivative, and Type XII, a selection from East Malling Station; both are reproduceable asexually. As the natural occurring trees for test were to be the foundation of clons of their somatic tissue, all propagation of them will of necessity be asexual.

At present a test of 185 clons for stock potentialities is being conducted and has progressed to the sixth step of the proposed program. Most of these are selected wildings, a few are approved American and European clonal stocks, and several fruit bearing varieties are included. The latter were placed in the trial to determine their growth capacity, for it is considered desirable to have a rating of the growth of stocks in reference to that of the tops which may be combined with them.

The procedure devised to bring out various characteristics of these clons and to furnish possibilities for responses by which they might be appraised, is discussed in the following paragraphs:

1. To give some conception of their compatibility with domestic apples and capacity to produce dry matter these apple wilding clons (to be referred to as stock clons), were budded onto straight rooted domestic seedlings which had been commercially produced from Jonathan, Delicious, and Rome seeds. Twelve seedlings were budded with each stock clon with the expectation of getting at least 10 budlings. If any of these stock clons on seedling roots show real promise they should be used as self-rooted plants for fruit tree stocks. Woolly aphids were not controlled but leaf hoppers were inhibited by frequent spraying.



FIG. 2. Root grafts not showing scion rooting and showing scion rooting.

2. To determine the ability of these stock clons to root from the scion and to observe the characteristics of the root production and development, also to obtain roots for propagation by root cuttings grafts were made using the stock clons as scions. A dozen grafts of each clon were made and wrapped above the union with wire to cause

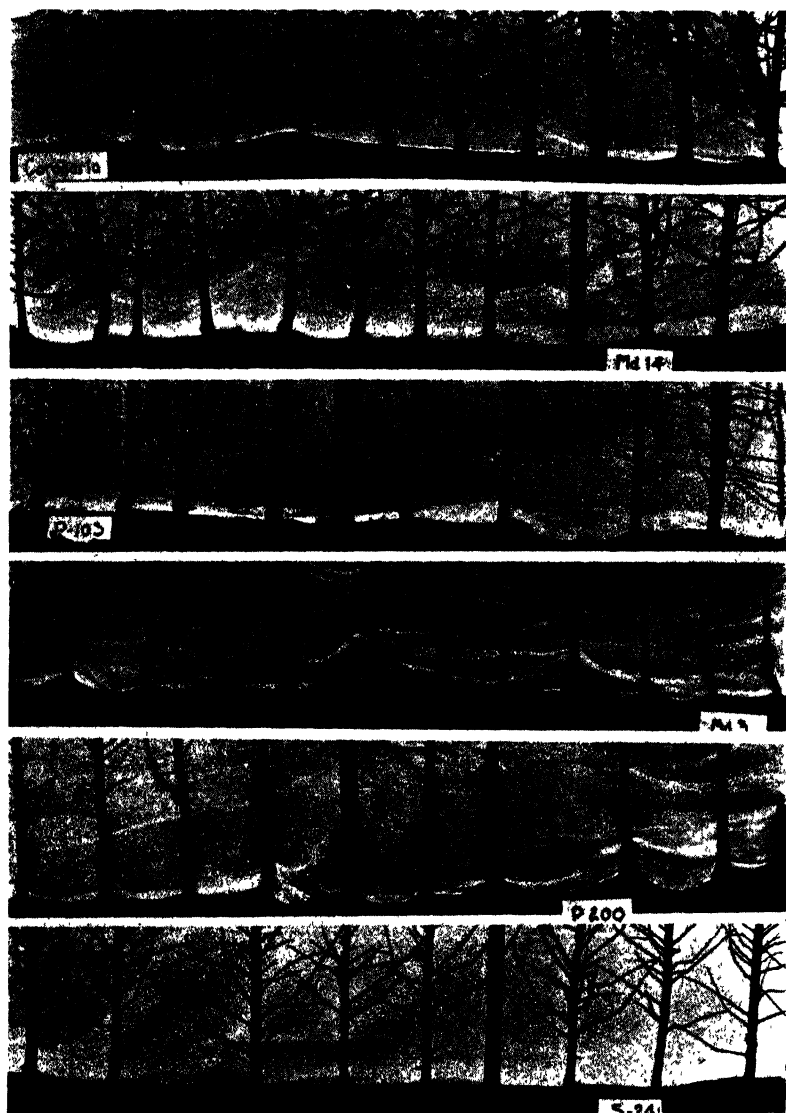


FIG. 3. Stands of uniform budlings.

subsequent girdling which frequently induces the formation or development of roots in the scion. After 2 years of growth the amount of self-rooting and the characteristics of the scion roots may be observed (Fig. 2). These clonal roots when they become sufficiently large may be made into cuttings for trial of propagation by this means.

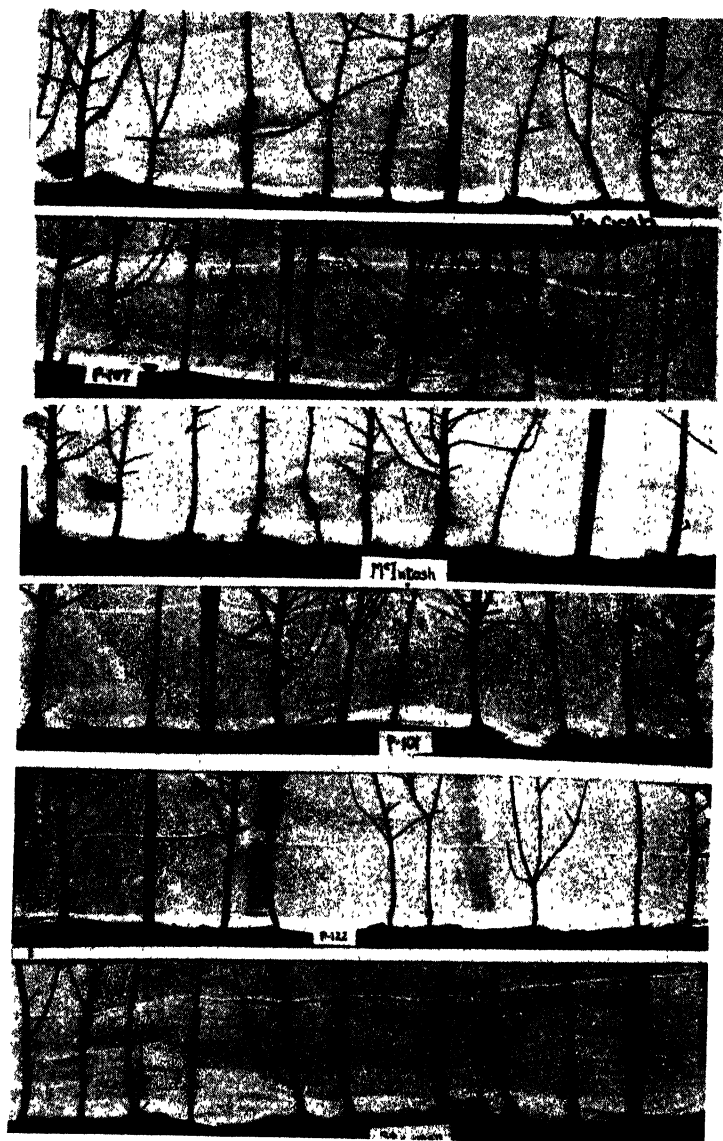


FIG. 4. Stands of ununiform budlings.

3. The stock clon budlings should be observed during the first and second years for characteristics, weaknesses, and promising tendencies. Some of the characteristics observable are: uniformity of plants (Figs. 3, 4), types of growth—as branch distribution and branch angles, bark color, resilience of wood and specific leaf characters which might be useful in roguing. The weaknesses exhibited may be poor stand of budlings, infections and insect preferences, unequal growth at union, brittleness of wood and roots. Some other desirable features are the continuance of growth during dry periods, the duration of the green stage and the modification of root distribution and configuration.



FIG. 5. Seedling roots 4 years old grown under their own tops. Budded with own buds in second year.

4. For a further test of compatibility and adequate systemic functioning the stock clon budlings were budded with comestible clons (varieties for food production), during the second growing season. With the test at present in progress, buds of two comestible clons were used, Stayman and York. The survival of the York buds was of much interest for they appeared to be more restricted in their compatibility than those of Stayman. G. D. Yerkes considers that York, Rome and Gallia Beauty are exacting in respect to stock preferences. I have learned that Gordon Brown of Hood River Station has experienced that Yellow Newton also is very limited in compatibility with stocks. Budding to large stems may not be a fair test for the ability of buds to survive. In using 2-year-old stems of the stock clon budlings, about half were large and in tying the buds sufficient pressure may not have been brought on them, especially when the bud wood was small as in the case with York.

The inspection in the fall of buds for survival disclosed that York had completely failed on 38 stock clons and partially failed on 51 others. Stayman buds showed only seven complete failures and 34 partial failures. These figures should not be seriously considered, for

the number of buds placed were too small, being only two of each variety on each stock clon. The failures will be scion grafted to make the compatibility observations more certain.

5. Weight is the only real estimate of the ability of such a heterogeneous group of material to deposit dry matter for they differ independently in the relations between their other dimensions. In the second dormant period of the stock clon budlings they were dug to obtain their weight and to observe the possible modification of the seedling roots by the stock clon tops. The range of weight of 10 trees of each clon was from 2.58 to 9.96 kilograms. It was very evident that some of the stock clons had modified the roots under them (Figs. 5 and 6). After a very casual study of the photographs of the roots developed under 50 selected stock clons it was easy to decide that there were six or eight very definite root forms which were each constant for specific clons. It would be very desirable to have enough trees of each combination to be able to fractionate some to obtain the top-root ratio. While at present the further use of these trees precluded the possibility of obtaining this measurement, it was very evident that there would be marked differences in the value of the ratio if it could have been obtained. These roots were grown in fertile sandy loam soil.

The appearance of woolly aphis on the seedling roots under certain of the stock clons and their absence under many of the others leads strongly to the belief that the top must have had much to do with the presence of the aphis under them, for the roots of all the stock clons budlings were originally similar.

6. At this point the lifted budlings of each stock clon are divided into two groups, one for resetting and the other for trench layering. Those reset were the ones bearing comestible clon buds and one of the stock clon budlings. This was done to determine the survival and growth response of the comestible clons growing over an intermediate piece of the stock clons. It was also done to observe the advent of the reproductive status of both the stock clon as a top and the comestible clons grown above the intermediate stock piece. Several of the trees of each stock clon group were trench layered to test the facility of the various clons to reproduce by this method.

This program will, in 5 years' time, yield a fairly complete picture of many potentialities portrayable by trees in the juvenile state; their ability to combine with comestible clons; their tendency to deposit dry matter; ability to modify seedling roots; ability to form roots in the scion; ability to reproduce from root cuttings and the character of regenerated roots. This scheme has a value in that a large number of stock clons may be investigated simultaneously. A score card might be prepared by which a record and rating could be taken each year for the characters then under observation.

A consideration which should be kept in mind is that young trees may exhibit a strong tendency to deposit much dry matter and yet reach the reproductive status early, resulting in a bearing tree of small to medium size. Furthermore, some stock clons may appear to be very desirable when judged by their performance in a test of short duration as this one, but later be disappointing as stocks, for besides

a good tissue union there must be an adequate integration of the functioning of the parts to make an effective individual.

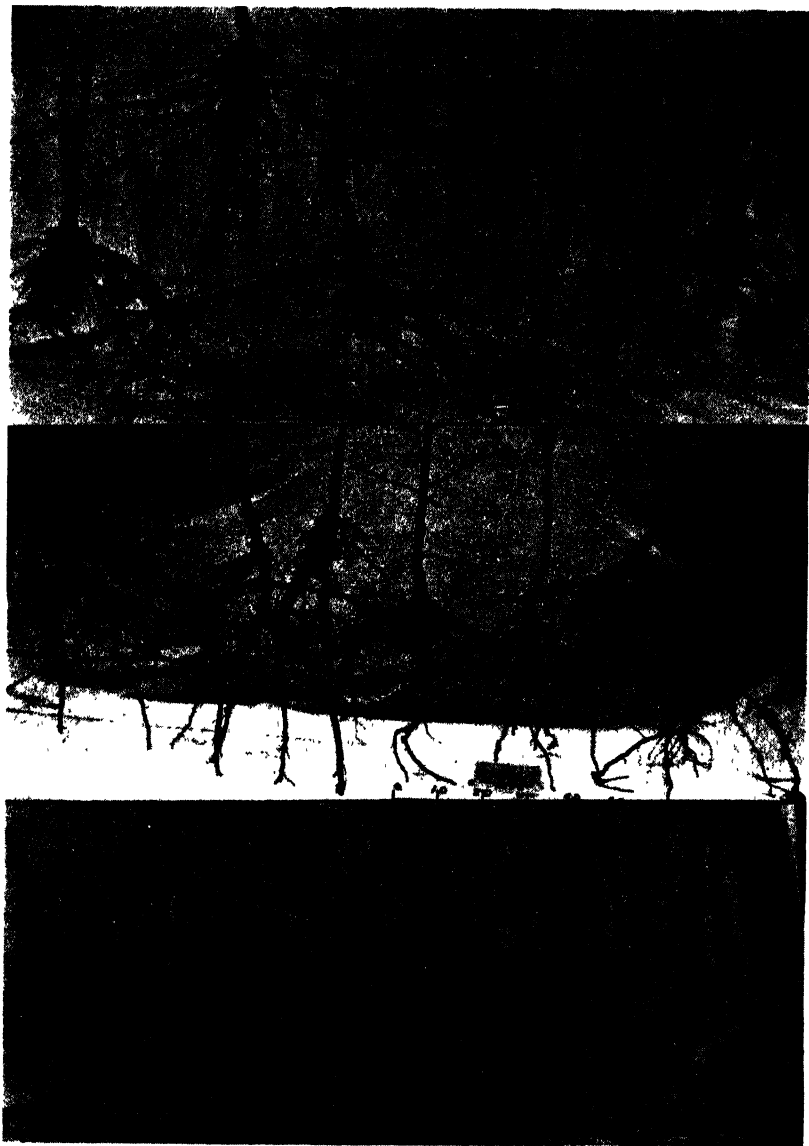


FIG. 6. Seedling roots 4 years old, the last 2 years they carried clonal tops.
Note specific modification.

If the above program does not result in the discovery of some desirable stock clons it will have been a most valuable and instructive experience for the investigator.

Comparison of Root Development of Clonal and Seedling Understocks With Apple Varieties Under Orchard Conditions

By I. C. HAUT and A. L. SCHRADER, *University of Maryland, College Park, Md.*

IN the spring of 1929 an orchard planting of certain apple varieties propagated on various clonal understocks and on French Crab seedlings was undertaken as a cooperative project between the Maryland Experiment Station and the Division of Horticultural Crops and Diseases, United States Department of Agriculture. In the spring of 1931 this planting was extended to include additional varieties and understocks.

This paper presents data showing the comparative root development of a 7-year-old Delicious tree on a clonal stock known as Vermont 323¹ compared to one on a French Crab seedling, and 5-year-old Starking and Yellow Newtown trees on a clonal stock Spy 227¹ as compared to the French Crab. The Delicious tree was included in the 1929 planting which consisted of 19 trees of this variety on Vermont 323 and 16 trees on French Crab seedlings set in adjacent rows. Both the Starking and Yellow Newtown were set in 1931 in adjacent blocks of three rows each with 10 trees in the row. The middle row of trees was in each case on the French Crab seedlings and the row on either side on the Spy 227 clonal stock. A spacing of 20 x 20 feet was used with all varieties. The Delicious, Starking, and Yellow Newtown were selected for this study because of the markedly greater top growth which the trees of these varieties have made on the respective clonal understocks as compared to those on the French Crab seedlings (Table I).

The soil in the Delicious block is classed as a Sassafras sandy loam with a deep loamy sand subsoil. In the Starking and Yellow Newtown blocks the soil is a gravelly loam with a gravelly bluish clay subsoil mostly impervious. These soils have low natural fertility.

The soil management system has consisted of annual cultivation with cover crops of rye and vetch in September and occasional cover of cowpeas or Sudan grass in June. An application of a 4-8-5 fertilizer at the rate of 300 pounds per acre was made with the cover-crop, and sodium nitrate at the rate of $\frac{1}{2}$ pound per tree for each year of growth was annually applied.

In this study, one-half of the root system was removed from each of two trees of a variety, one tree in each case being on the clonal stock and the other one on the seedling stock. Adjacent trees representing the average size for trees on each stock were selected. The method of excavation consisted in the removal of the soil in semi-circular zones of 0-2, 2-4, 4-6, and 6-8 feet from the tree trunk and at depths of

¹These stocks were selected and named by G. E. Yerkes, U. S. Department of Agriculture. Others have also designated these stocks as U. S. or U. S. D. A. 323 and U. S. or U. S. D. A. 227.

0-6, 6-12, 12-24, 24-36, and 36-48 inches. With all trees the 8 foot distance from the trunk was more than the spread of the branches (Table I).

The soil from each zone of the excavated side was placed in a separate pile and the roots removed by carefully "badgering" through the soil. The roots were then air dried in the laboratory after which they were graded into six classes based on diameter. These diameters were as follows: under $\frac{1}{16}$ inch, $\frac{1}{16}$ to $\frac{1}{8}$ inch, $\frac{1}{8}$ to $\frac{1}{4}$ inch, $\frac{1}{4}$ to $\frac{1}{2}$ inch, $\frac{1}{2}$ to 1 inch, and over 1 inch. The dry weight of each class was recorded in grams.

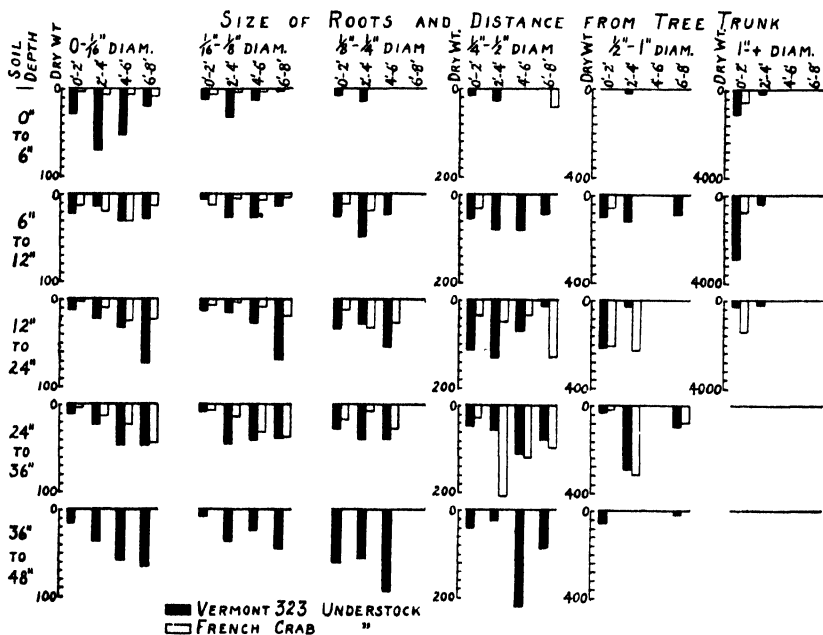


FIG. 1. Comparative root development of 1-year-old Delicious apple trees on two understocks, based on dry weight (grams) and sizes of roots occurring in several soil zones.

Following the excavation of the root system on the one side, the remaining side of each tree was carefully dug retaining the gross root system as completely as possible for additional observations. The total weights of the tops were also in each case recorded and moisture determinations made of twig, branch, and trunk portions.

The results for the Delicious, Starking and Yellow Newtown trees on each stock are graphically illustrated in Figs. 1, 2, and 3, giving the dry weights based on one-half of each root system.

A study of the data presented in Fig. 1 shows that the Delicious tree on the Vermont 323 stock had the greater root weight in almost every soil zone regardless of the size classification. It also had the greater depth of rooting. This was the only tree of those herein reported which had rooted to a depth greater than 36 inches. One root

in the 2-to-4-foot zone extended beyond the 48-inch depth to a depth of 64 inches. The weight is not recorded in Fig. 1.

In the case of this Delicious tree on the Vermont 323 stock, rooting extended beyond the 8-foot distance from the trunk. However, upon examination preparatory to digging an 8-to-10-foot zone, an overlapping of roots from the adjacent tree was evident. Therefore, since the number and size of these extending roots were relatively small, a record was made of their size and location of the larger roots. The two largest roots were slightly over $\frac{3}{8}$ inches in diameter and were found to extend 11 feet 3 inches, and 10 feet 9 inches from the trunk. The greatest lateral root development of this tree occurred on the opposite side, the three longest roots here extending 17 feet 11 inches, 14 feet 9 inches, and 12 feet 10 inches from the trunk. With the Delicious tree on the French Crab seedling stock only two roots extended beyond 8 feet, one being 10 feet 4 inches and the other 10 feet 1 inch from the trunk, and both occurring on the side opposite from that which was excavated.

The spread of the tops, total top weights and trunk areas at the ground level of the Delicious trees on these two understocks and the ratios between the two are shown as a part of Table I. The amounts and ratios of the dry weights for the various sized roots between these stocks are also shown in this table. It is of interest to note that the ratio of the top weights of the trees on these two stocks as compared to the ratio of the total root weights indicates that the Delicious on the French Crab seedling stock had greater total weight of roots in proportion to the top. The high ratios for the under $\frac{1}{16}$, $\frac{1}{16}$ to $\frac{1}{8}$, and $\frac{1}{8}$ to $\frac{1}{4}$ inch diameters, however, indicate that the Vermont 323 stock had the

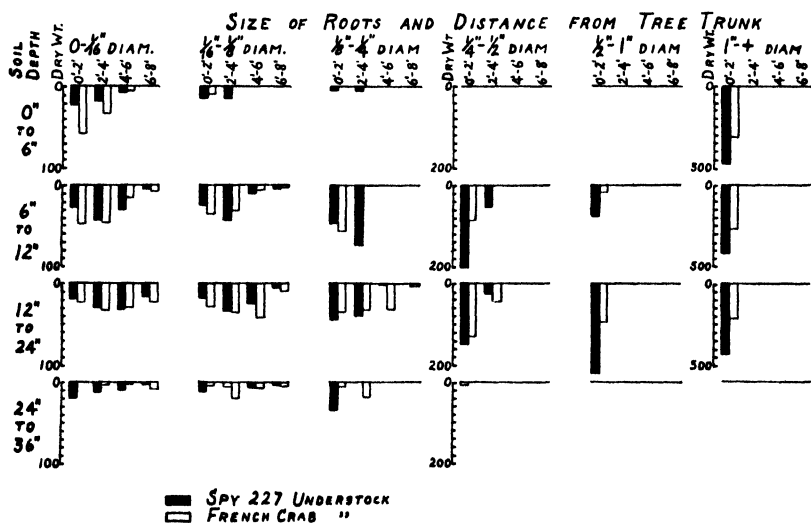


FIG. 2. Comparative root development of 5-year-old Starking apple trees on two under-stocks, based on dry weight (grams) and sizes of roots occurring in several soil zones.

TABLE I—COMPARATIVE TOTAL DRY WEIGHTS OF ROOTS OF VARIOUS DIAMETERS DEVELOPED BY TWO DIFFERENT UNDERSTOCKS ON THREE APPLE VARIETIES

Variety	Spread of Top (Inches)	Top Weight (Pounds)	Trunk Area (Sq. Ins.)	Dry Weight of Roots for Indicated Diameters in Inches					
				Under $\frac{1}{8}$ Grams	$\frac{1}{8}$ — $\frac{1}{4}$ Grams	$\frac{1}{4}$ — $\frac{1}{2}$ Grams	$\frac{1}{2}$ —1 Grams	Over 1 Grams	Total Grams
Starking on Spy 227	134	79.5	14.19	280	209	431	308	1304	2776
Starking on French Crab	107	38.5	8.92	329	230	254	100	804	1902
Ratio Spy 227/French Crab . .		2.06	1.59	.85	.91	1.32	3.08	1.62	1.46
Yellow Newton on Spy 227	105	30	8.92	104	75	118	124	766	1300
Yellow Newton on French Crab . .	91	24.5	7.65	129	92	75	91	576	1064
Ratio Spy 227/French Crab	—	1.22	1.17	.81	.82	1.04	1.36	1.33	1.22
Delicious on Vermont 323	178	178.5	37.07	686	478	1251	1050	4909	9070
Delicious on French Crab	140	79	22.65	240	159	738	909	2665	4933
Ratio Vermont 323/French Crab		2.26	1.64	2.86	3.01	3.14	1.70	1.84	1.84

more fibrous root system, and apparently more uniformly distributed as indicated in Fig. 1.

The data for the Starking and Yellow Newtown varieties on the Spy 227 and seedling stock are found in Figs. 2 and 3 respectively. With both varieties the greater root weight is found for the clonal stock. As with the Delicious, the ratio of the top weights of the Starking trees as compared to the ratio of the total root weights indicates that the tree on the seedling stock had the greater total weight in proportion to the top. With the Yellow Newtown, however, these ratios were the

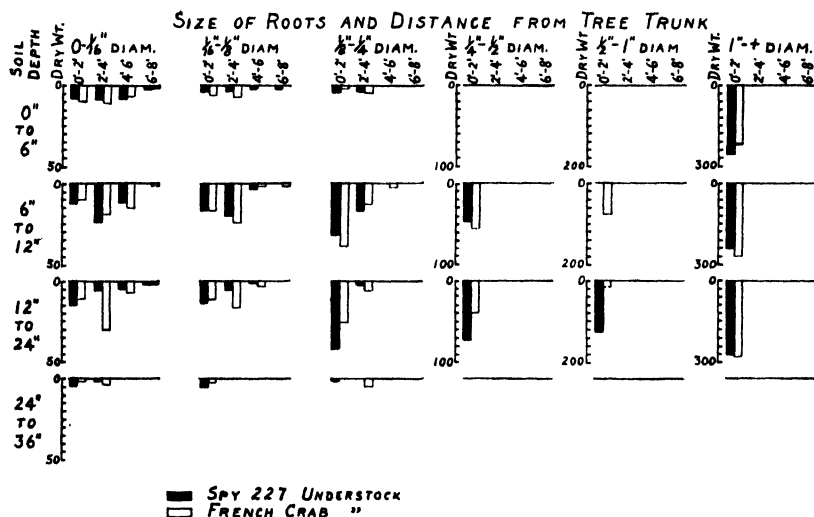


FIG. 3. Comparative root development of 5-year-old Yellow Newtown apple trees on two under-stocks, based on dry weight (grams) and sizes of roots occurring in several soil zones.

same (Table I). Conversely to the Delicious, the low ratios for the under $1/16$, $1/16$ to $1/8$ and $1/8$ to $1/4$ inch diameters indicate that the seedling stock with both the Starking and Yellow Newtown had the more fibrous root system.

Since the spread of the tops, top weights and trunk areas given in Table I for each of the varieties on their respective stocks closely approximate the averages for all trees in each case, the increased growth which had resulted from the use of these clonal stocks as compared to French Crab seedling is clearly evident with the Delicious, Starking, and Yellow Newtown varieties.

However, the larger top size is not explained easily on the basis of relative amounts or distribution of roots, except that Vermont 323 showed a greater relative proportion of smaller roots and possibly a better distribution of roots through the several soil zones. This result indicates that the stimulation of top growth on the clonal stocks must be largely explained on other bases as yet unknown. The lack of congeniality of Spy 227 with other varieties, notably Grimes in this experiment, indicates this same conclusion.

The Effect of Pruning on Yields of Own-rooted and Seedling-rooted Apple Trees

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DETAILS pertaining to the planting and development of the trees dealt with in this study have been given previously (1, 2, 3) so are here omitted. The trees have just passed through their eighth growing season in the orchard under a fertilizer-cultivation-cover crop system of soil management. They are so planted that unpruned scion and seedling rooted trees of a variety alternate within a row. The same holds true for the pruned trees. Also the pruned and unpruned rows of a variety are planted alternately.

METHOD OF PRUNING

All trees had about one-half of their terminal growth removed at the time of planting and, thereafter, those receiving pruning were dormant pruned yearly, except in 1933, to a semi-leader type of tree. No heading back of new growth was practiced except in the case of wayward branches. The scion or own-rooted trees had the nurse or seedling roots removed at time of transplanting to the orchard. The unpruned trees have been given no pruning whatsoever except at time of planting.

RESULTS

The effect of pruning these young trees has been in general as reported by others, to reduce the yield of fruit, or delay fruiting. This effect of pruning was pronounced regardless of whether the trees were growing on their own roots or on French Crab roots. It is observed from Table I that there were only two instances out of 22 where the yield of the pruned trees exceeded that of the unpruned trees, and they were not statistically significant differences. The decreases were statistically significant in eight instances, of which three occurred with scion rooted trees and five with seedling rooted trees. Accordingly, in this case, it might be said that pruning has decreased the yield of trees on seedling roots to a greater extent than trees on their own roots. The figures are not presented, but this was actually found to be the case when the results were expressed on a percentage basis.

There is another effect resulting from pruning these trees that it is desired to lay particular emphasis on, for undoubtedly the same effect is present, but seldom given adequate consideration in many physiological and nutritional studies with fruit trees. It is the effect pruning has on the variability in yield of the trees. Of course with studies on mature trees and when considered from a practical viewpoint, it is evident that some pruning or training must be given the trees. However, it is of interest and value to know whether one decreases the variability in yield of young apple trees by pruning or whether it is increased. If their variability in yield is increased by pruning, it would seem advisable that no pruning or, at least as little as possible, be given young trees that are under physiological or nutritional investigation. For, even if they are never grown to fruiting age,

TABLE I—EFFECT OF PRUNING ON YIELD AND VARIABILITY OF SCION AND SEEDLING ROOTED APPLE TREES

Treatment	Year	Yield per Tree (Pounds)				Coefficient of Variability							
		Scion		Seedling		Scion		Seedling		Scion		Seedling	
		Yield	P. E.	Yield	P. E.	C. V.	P. E.	C. V.	P. E.	C. V.	P. E.		
<i>Yellow Transparent</i>													
Unpruned Pruned	1934	.81	.20	.58	.06	98.76*	16.65	40.86	6.89				
		.58	.12	.23	.05					95.68	14.43	92.17	15.54
Diff. and P. E. D.		-.23	.23	-.35	.08	-3.08	16.93	+52.71†	17.00				
		5.68	1.50	2.92	.65	103.71*	17.49	87.05*	14.68				
Unpruned Pruned	1935	4.53	.61	3.92	.52	59.75	9.01	52.34	8.83				
		-1.15	1.62	+1.00	.83	-43.96	15.70	-34.71	17.13				
Diff. and P. E. D.		59.82	11.41	36.76	6.11	74.79*	12.61	65.17	10.99				
		38.45	3.58	22.41	4.21	41.45	6.25	73.62	12.41				
Diff. and P. E. D.		-21.37	11.96	-14.35	7.4	-33.34	14.75	+8.45	16.58				
		<i>Delicious</i>											
Unpruned Pruned	1935	.50	.30	2.99	.87	249.00	39.57	130.00	19.60				
		-50	.30	-2.99	.87	-249.00	39.57	-130.00	19.60				
Diff. and P. E. D.		1.72	.47	24.71	5.48	114.76	18.24	98.58	14.87				
		—	—	3.31	1.64	—	—	220.12	33.19				
Unpruned Pruned	1936	-1.72	.47	-21.40†	5.72	-114.76	18.24	+131.54†	36.36				

Unpruned Pruned	1935	Rome Beauty							
		4.94 5.90	.92 1.21	12.11 8.72	1.42 1.36	137.85 139.94	12.89 14.22	86.95 118.11	8.13 10.83
Diff. and P. E. D.	1936	+ .96	1.52	-3.39	19.7	+2.09	19.19	+31.16	13.54
		21.23 6.17	3.06 .90	27.62 5.74	3.78 1.05	106.78* 99.33	9.98 10.09	101.33 139.00	9.45 12.75
Diff. and P. E. D.		-15.06†	3.19	-21.88†	3.92	-7.45	14.19	+37.67	15.87
Unpruned Pruned	1935	Stayman							
		11.91 10.39	1.58 1.74	27.88 13.60	3.07 3.61	55.53 74.61	8.82 11.25	46.19 111.39	7.34 17.70
Diff. and P. E. D.	1936	-1.52	2.35	-14.28†	4.74	+19.08	14.30	+65.20†	19.16
		85.58 32.07	9.27 5.83	70.60 46.60	8.86 9.93	45.41 80.89	7.22 12.20	52.59 89.31	8.36 14.19
Diff. and P. E. D.		-53.51†	10.95	-24.00	13.30	+35.48	14.18	+36.72	16.47
Unpruned Pruned	1935	Grimes							
		37.43 28.41	4.17 3.52	54.65 20.81	6.85 2.36	71.97 75.81	7.67 8.52	71.89* 65.09	8.57 7.76
Diff. and P. E. D.	1936	-9.02	5.46	-33.84†	7.25	+3.84	11.46	-6.80	11.56
		48.30 18.77	5.04 2.16	76.90 18.34	9.54 3.15	67.41 70.29	7.19 7.90	71.24 98.63	8.49 11.76
Diff. and P. E. D.		-29.53†	5.48	-58.56†	10.04	+2.88	10.68	+27.39	14.51

C. V. = Coefficient of Variability.

P. E. = Probable Error.

Diff. and P. E. D. = Difference and Probable Error of the Difference

*Indicates the few instances where the C. V. of the unpruned trees was higher than that of the pruned trees, although none were significantly so.

†Indicates a difference at least three times the P. E. & Diff.

if the effect of pruning is such that it increases the variability of their yields as they come into bearing, it would seem reasonable to expect that their variability has also been increased relative to the factors upon which fruiting is dependent and which probably precede it.

It is observed from the coefficients of variability on yield presented in Table I that they are higher in the case of the pruned trees in 13 of the 19 instances. It would seem, therefore, that there is a definite trend toward increased variability in yield as a result of pruning, although the probable error of the differences indicate significant differences in only three of 19 instances.

Although the data comparing the yield of *unpruned* scion and seedling rooted trees is not presented in most convenient form for study, the following statement pertaining to it is made as a matter of interest and record at this time. The seedling-rooted trees have with the exception of the variety Transparent averaged more fruit per tree than the unpruned scion-rooted trees; although the differences have been statistically significant in only three instances. When these unpruned trees were compared on the basis of their variability in yield, it was found that the seedling rooted trees have been less variable in nine out of 11 instances although significantly so in only two.

A comparison of the *pruned* scion and seedling rooted trees showed the scion rooted trees to have outyielded the seedling rooted ones in six of ten instances. When the variability of these *pruned* trees was compared, it was found that the scion-rooted trees were less variable than the seedling rooted trees in five of nine instances.

In summary, the effect of pruning on the yield of young apple trees has been to reduce the quantity of fruit they produce and to increase their variability as individuals, with respect to yield. It is suggested that for nutritional studies, other than pruning, to be carried on with young trees for a short period of years, where yield is concerned, that no pruning be given the trees used.

It was also shown that pruning influenced seedling-rooted trees to a greater extent than scion-rooted trees. However *unpruned* seedling-rooted trees have in general yielded more fruit to date than unpruned scion-rooted trees and have shown less variability in yield. Pruning seriously changed the normal behavior of the trees by decreasing their yield and increasing their variability. In the case of the *pruned* trees it was found that the scion-rooted trees in general outyielded the seedling-rooted ones and also were less variable.

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Etiolation as a Method of Rooting Apple Variety Stem Cuttings

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IT is well known that stem cuttings of apple varieties do not root to any appreciable degree by the usual procedures employed with cuttings of many other plants. A summary of the many attempts to root apple stem cuttings has been published (1) and detailed references will therefore be omitted here. It is also unnecessary to point out the advantages and possible benefits that a practical method of rooting these cuttings would secure.

For some years the author has been interested in the rooting of apple cuttings and, to this end, has tried many methods and treatments. No useful purpose would here be served to recount the various unsuccessful attempts and disappointments. On the other hand, one method, that of etiolation, has been very encouraging and has been modified and improved from year to year, so that it can now be reported as a method of some practicability.

Etiolation, a condition resulting from growth in complete or nearly complete absence of light, is a term which as yet conveys little definite meaning from the physiological or anatomical viewpoint. Why etiolation should favor the production of roots from stem tissue is as much "in the dark" as the implication of the term itself. It is, however, common knowledge among propagators that, for the best success in the propagation of plants by the layering method, the soil should be drawn up around the young shoots as early as possible, before the tissues become mature and woody. No doubt, etiolation, is an important factor in the production of roots from stem tissue by layering.

In applying this principle to stem cuttings, the first problem was to devise a way of etiolating the shoots as they grew on the tree, before removing them for cuttings. For this purpose, ordinary black insulating tape was used (Fig. 1, A). A piece $2\frac{1}{2}$ to 3 inches long is sufficient to wrap spirally four or five times around the young shoot as near the growing tip as possible. The partially expanded leaf or two near the tip are first removed, for if they are bound to the stem all further shoot elongation may be checked. When properly applied, the tape does not interfere with shoot elongation nor with radial growth because the tape gives as the stem diameter increases, constantly keeping a snug, light-tight covering over this short section of stem during its subsequent development. The application of tape is so readily accomplished that one man can easily tape several thousand shoots in a day, if the size of tree permits working from the ground.

When cuttings are to be made, it is only necessary to remove the shoot, strip off the tape and make the basal cut in the etiolated area. By this method, rooting of cuttings up to 70 per cent in the propagating bench was obtained in the case of McIntosh. If the etiolated shoots were girdled early in their growth by means of copper wire, 100 per cent rooting could be obtained. Girdling alone, however, was of no avail.



FIG. 1. A, Method of taping. *Left*, just taped. *Right*, 2 days later. B, Showing etiolated condition of shoot when black bag is removed. Normal shoot of same age on the right.

Intosh trees were entirely covered in the spring just before bud break, with large light-tight boxes constructed of black water-proof paper nailed on wooden frames. When 2 or 3 inches of shoot elongation had taken place the boxes were removed and all of the etiolated shoots were promptly taped around the base of the current growth. Except for this short taped section of stem the shoots then continued their development in the light.

The following March, cuttings were made from the shoots etiolated in this manner and placed in the propagating bench. From a total of 80 cuttings, 78 rooted vigorously in 2 weeks time (Fig. 2). Due to the presence of many closely arranged nodes at the base of apples shoots, each cutting produced a number of roots instead of the single

Most of this early work was done with McIntosh variety and it was soon discovered that one or two roots appeared on the cuttings and these were only from the axil of the buds. Taping of internodes only, in the case of McIntosh, was entirely without benefit. It was further discovered that if the young shoots were taped to within 1 inch of the growing tip, instead of as close to the tip as possible, the subsequent rooting markedly fell off. By leaving 2 inches back from the tip untaped the rooting was still further reduced, and with 3 inches untaped, almost no rooting resulted. This indicated the necessity of etiolating early in the differentiation of the tissues of the growing tip. It also pointed out the probability that even better rooting would result if the etiolation could be accomplished without allowing the tip on which the tape was applied to make its initial growth in the light. In order to test this point, 5-year-old Mc-

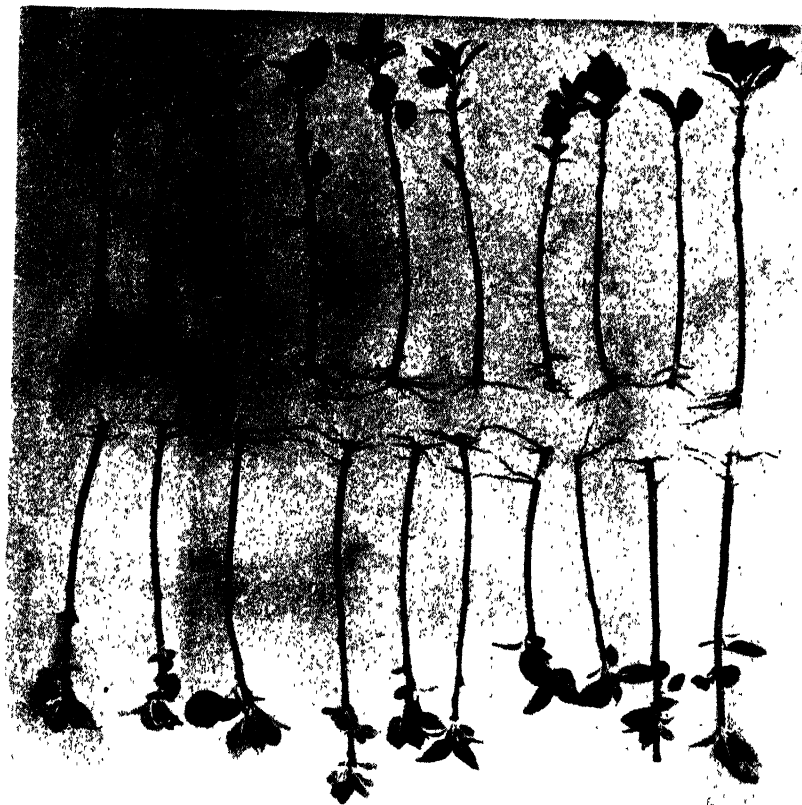


Fig. 2. Rooted cuttings of McIntosh 2 weeks after placing in propagating bed in March. The shoots made their initial growth under a black box and were subsequently taped.

root or two which characterizes an etiolated section higher on the stem where considerable space occurs between nodes and only one node can conveniently be covered.

The much greater success of this method than where taping alone was practiced, led to an attempt to make the method more adaptable for use. The following spring, instead of large boxes to cover entire young trees, narrow cylindrical bags about 10 inches long were made of heavy black mulching paper and fastened over individual shoots so that the initial few inches of growth could be made inside these rigid coverings (Fig. 3, B, and Fig. 1, B). These were subsequently removed and tape applied as before.

The rooting response of cuttings treated in this way varied from relatively poor rooting (30 to 40 per cent) up to 100 per cent, depending upon the condition of the shoot, the time of year with respect to its rest period, and upon the variety. Some varieties are inherently more

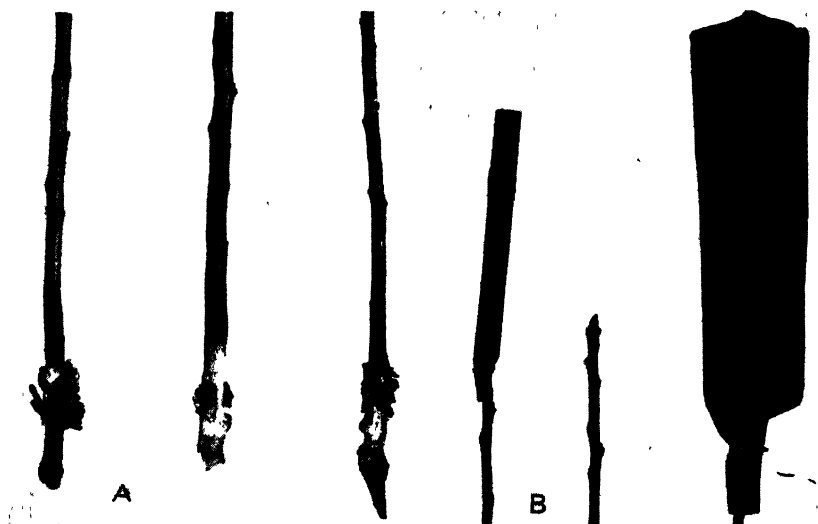


FIG. 3. A, Northern Spy shoots as tape is removed, showing advanced stage of root primordia. Northern Spy is an exaggerated case. B, Method of applying black bags (right) and the tubes (left) before growth starts.

responsive to etiolation than others. Opalescent, Northern Spy, McIntosh, Baldwin, Fameuse, Northwest Greening, and Tompkin's King have given excellent results, whereas, of all the varieties tried, Wealthy, Williams, Yellow Transparent, Golden Delicious and Tolman have been least responsive. No variety, however, has failed to root to some extent by this method.

The prompt rooting response of the cuttings (sometimes only 3 or 4 days) suggests that root primordia are pre-formed in the etiolated area during early growth, just as they occur naturally in *Salix* and a number of other plants, and making the cutting simply furnishes the stimulus for these primordia to elongate. In fact, the primordia are often quite evident to the eye when the shoots are taken from the tree and the tape removed (Fig. 3, A). In McIntosh, they appear as slight "pimples" in the bud axils; in Northern Spy, Opalescent, Delicious, Perkins, Rome Beauty, Summer Rambo and Northwest Greening, they may occur as very obvious projections from the stem, sometimes having grown out under the tape to a length of $\frac{1}{2}$ inch.

It is of interest to note that if tape is not applied to the young etiolated shoots at the time the black bags are removed, cuttings subsequently made do not root. However, as already mentioned, the taping of non-etiolated shoots 3 inches back from the tip also fails to stimulate root production. It is probable that, in the absence of light, the initial stages of root primordia formation or perhaps the predisposition of certain cells to this development, take place before much differentiation of primary tissues has occurred and that some period of continued darkness is necessary to permit further development of these primordia.

In this connection, etiolated cuttings taken early in September, from which the tape had been removed 1 month earlier, rooted almost as satisfactorily as those from which the tape was not previously removed.

The place of occurrence of the root primordia in relation to the bud is of special interest and differs among varieties. In Tompkin's King, Fallawater, Northwest Greening, Red Astrachan, McIntosh, Stayman and Wagener, for examples, the primordia occur within the axil of the bud, whereas in Winesap, Winter Banana and Northern Spy, they occur to one side and somewhat below the bud. In Jonathan and Grimes Golden the primordia sometimes occur in the bud axil but more frequently at some undetermined point on the internode. In general, only one or two roots arise from these primordia locations, although in Northern Spy and Winter Banana large patches of many roots appear.

A definite relationship exists between time of year of taking the etiolated cuttings (reflecting their activity for growth) and the quickness and completeness of the rooting response. Cuttings taken in early August and stripped of their leaves will root very promptly and vigorously provided the shoots from which they are taken are not too vigorous and have had opportunity to accumulate some reserve carbohydrates by that date. Prompt rooting can be secured as long as the top buds of the cuttings can be stimulated into activity, but as the shoot enters deeper into the resting condition the elongation of the primordia into roots becomes more sluggish as is evidenced by increasing slowness of rooting and the smaller number of roots per cutting. The course of this rooting was followed by taking 25 cuttings of McIntosh at 2-week intervals throughout the fall and winter months, beginning August 15, at which time 100 per cent rooting was secured in 14 days. The rooting became progressively poorer until early spring when prompt rooting was again obtained after the rest period of the buds was terminated.

Any method of rooting apple cuttings to prove commercially feasible should, it is believed, be adaptable to field conditions. With this in view, etiolated cuttings were set to root directly in the nursery late in August and also as early in the spring as the ground could be prepared. In the limited tests thus far made in the field, fall planting has been more successful than spring planting, due to the warm friable condition of the soil which favored prompt rooting of the cuttings. As rooting occurs, a few small leaves unfold at the tops of the cuttings but elongation of stem does not proceed until spring. The percentage stand and the vigor of growth from fall planted cuttings have compared very favorably with the stand and growth from bench grafts of the same varieties on piece roots (Fig. 4, A and B). From spring planting, the only variety thus far giving a satisfactory stand has been Northern Spy, due perhaps to the advanced condition of its root primordia when taken from the trees. The cold, wet soil condition in the spring is undoubtedly a factor in the poor showing made.

Although thorough etiolation by the method described has resulted in excellent rooting in the propagating bench and satisfactory rooting under certain conditions in the field, from the standpoint of practicability the process is subject to the objections that the bags are troublesome



FIG. 4. A, McIntosh trees 2 years old from etiolated cuttings planted directly in the field. (The label is 12 inches). B, Northern Spy trees one growing season from cuttings planted in the field in the spring.

to make and to fasten over the shoot terminals and that they must later be removed and tape applied. Furthermore, when the bags are removed, many of the resulting tender, white shoots are severely stunted or killed outright by the sun before chlorophyll can be produced and normal growth resumed.

In order to facilitate the etiolation process, paper tubes, $\frac{3}{8}$ inch in diameter and $5\frac{1}{2}$ inches long were made of black mulching paper (Fig. 3, B). In the spring before growth started on orchard trees, these tubes were tightly fastened over the ends of shoots by means of short pieces of copper wire, in such a manner that the new growth could push its way through the tube and emerge gradually into the sunlight. This method eliminated scorching of the etiolated shoot and also obviated the troublesome necessity of removing a covering in order to apply tape, for the tubes, once fastened, are left on until the cuttings are taken from the trees. From the standpoint of facility of application, this last modification of the etiolation method is quite satisfactory, although it is not certain from the single season's rooting results with its use that enough light may not have entered through the $\frac{3}{8}$ inch aperture of the tube to somewhat lessen the production of root primordia.

As to the possibility of their general application in plant propagation by cuttings, it should be mentioned that these etiolation methods have not been extensively tried with many other plants that are difficult to root. They have, however, in this study, been applied to lilac with excel-

lent results, to several varieties of pears with only indifferent success, and to sweet and sour cherry varieties without obtaining any rooting response. Smith (2) reported that Clematis, which ordinarily roots only at the internode, could be induced to root at the node if the stems had been previously wrapped with black paper strips.

The rôle which the absence of light plays in the differentiation of root primordia from stem tissue is not known. It can be surmised that a root-forming hormone is involved, although not enough information on the relation of light to growth substances is as yet available to warrant more than a conjecture. Possibly the absence of light brings about a temporary accumulation of growth substance in the etiolated region due to some anatomical abnormality. Anatomical studies of etiolated apple shoots in relation to their rooting response are now in progress.

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Nematode-Resistant Peach Rootstocks of Superior Vigor

By LEE M. HUTCHINS, *U. S. Department of Agriculture,
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INTRODUCTION

ROOT-KNOT of peach, caused by the nematode *Heterodera marioni* (Cornu) Goodey, has long been a serious problem for nurserymen and growers, in warm, well-aerated soils of the southeastern portion of the United States. Seedling peach understocks commonly used are so severely attacked by the nematode that peach nursery and orchard culture is impracticable on heavily infested, deep, sandy or sandy loam soils of this region. No orchard or soil management practices have been developed that will permit of successful peach production on these heavily infested soils. Root-knot infestation is undoubtedly a weakening factor in peach orchards in most producing areas of the Southeast.

The use of rootstocks resistant to the causal nematode offers a promising method for controlling root-knot of peach. Nematode resistance or susceptibility of a large assortment of fruit-tree seedlings, including several species, has been reported by Tufts (1) in 1929, and by Tufts and Day (2) in 1934.

Incidental to researches on the phony peach disease (3), peach trees propagated on rootstocks of plum, apricot, almond and several different peach varieties were grown in experimental nurseries and orchards from 1925 to 1936 at Fort Valley, Georgia. It is the purpose of the present paper to describe the results obtained as to the general suitability of the rootstocks tested, and their resistance to root-knot. Two peach rootstocks of superior vigor, namely, F.P.I. 63850 (Shalil) and F.P.I. 61302, have proved nematode-resistant. A brief preliminary account of the success with Shalil in these tests appeared in the Report of the Chief of the Bureau of Plant Industry (4), in 1934.

RESULTS

Five rootstock-test peach orchards have been grown, on old orchard land, though not all stocks have been tested in all orchards. Orchards Nos. 1 and 2, planted in January, 1928, consisted of Elberta budded or grafted on several stocks. Orchards Nos. 3, 4, and 5, planted respectively in 1931, 1932, and 1933, consisted of Early Hiley budded or grafted on various roots. From 30 to 100 or more trees on the respective rootstocks were used in each test. The following notes summarize the results.

Almond.—Forty-four Nonpareil almond seedlings, worked to the Early Hiley peach by scion grafting at the collar, were planted in rootstock orchard No. 3 in 1931. The trees were much dwarfed (Fig. 1) and many of them died within 4 years after planting. At Fort Valley, Georgia, almond seedlings usually come into flower and leaf during warm weather in midwinter and suffer from subsequent freezes. These seedling rootstocks have been variable in resistance to nematodes.



FIG. 1. Rootstock-test peach orchard, 4 years old. Left, Early Hiley on almond rootstocks; right, Early Hiley on rootstocks of F.P.I. 41498. Photographed at Fort Valley, Georgia, September 18, 1934.

Apricot.—Seedlings of the Blenheim apricot, from seeds obtained from California in 1925 and in different years thereafter, were budded or grafted to peach. All of the seedling apricot roots were completely resistant to root-knot, even on the most heavily infested soils, but peach trees propagated on them were noticeably less vigorous under orchard conditions than were trees propagated on peach rootstocks.

Japanese apricot (Prunus mume).—Seeds of this species were ob-



FIG. 2. Rootstock-test peach orchard, 4 years old. Showing: Left, foreground, seedling tree of *P. mume*, followed by row of Early Hiley trees on this rootstock; right, foreground, seedling tree of Arlington Farm No. 21868, followed by row of Early Hiley trees on this rootstock. Photographed at Fort Valley, Georgia, September 18, 1934.



FIG. 3. Rootstock-test peach orchard, 4 years old. Showing: left, Early Hiley trees on "natural" rootstocks; right, Early Hiley trees on rootstocks of *P. hortulana*. Photographed at Fort Valley, Georgia, September 18, 1934.

tained in different years from commercial seedsmen in the United States, and from the University of Nanking, China. In all the tests the seedling roots remained free from root-knot in heavily infested soil. Behavior of Early Hiley peach trees on this rootstock was tested in orchard No. 3, where 44 trees so propagated were planted. These trees were strikingly dwarfed (Fig. 2), and this rootstock is not regarded as satisfactory for commercial use as an understock for peach.



FIG. 4. Rootstock-test peach orchard, 4 years old. Showing: left, Early Hiley trees on rootstocks of F.P.I. 63850 (Shalil); right, Early Hiley trees on *P. davidiana* root stocks. Photographed at Fort Valley, Georgia, September 18, 1934.

Plum (*Prunus hortulana*):—This species has been highly resistant to root-knot in our tests, but it causes marked dwarfing (Fig. 3) and appears unsatisfactory as an understock for commercial peach trees.

Prunus davidiana:—This species was tested in repeated trials. Seeds obtained from Nanking, China, germinated readily and produced



FIG. 5. Seedling tree of F.P.I. 63850 (Shalil), 13 years old. Photographed at the U. S. Plant Introduction Garden, Chico, California, September 1927.

vigorous seedlings. The roots were susceptible to root-knot, however, and were easily infected with crown-gall. In orchards Nos. 1, 2, and 3, Elberta and Early Hiley were grown on this rootstock for several years. The trees were dwarfed (Fig. 4) and were very susceptible to winter injury of the collar-frost-girdle type.

Arlington Farm No. 21868:—This identification number was given to a peach type, seeds of which were introduced from China. Because of the vigorous growth and long life of seedling trees at the Arlington Experiment Farm, Roslyn, Virginia, it was included as an understock for 44 trees of the Early Hiley variety that were planted in orchard No. 3 in 1931. These trees grew rapidly (Fig. 2), and have

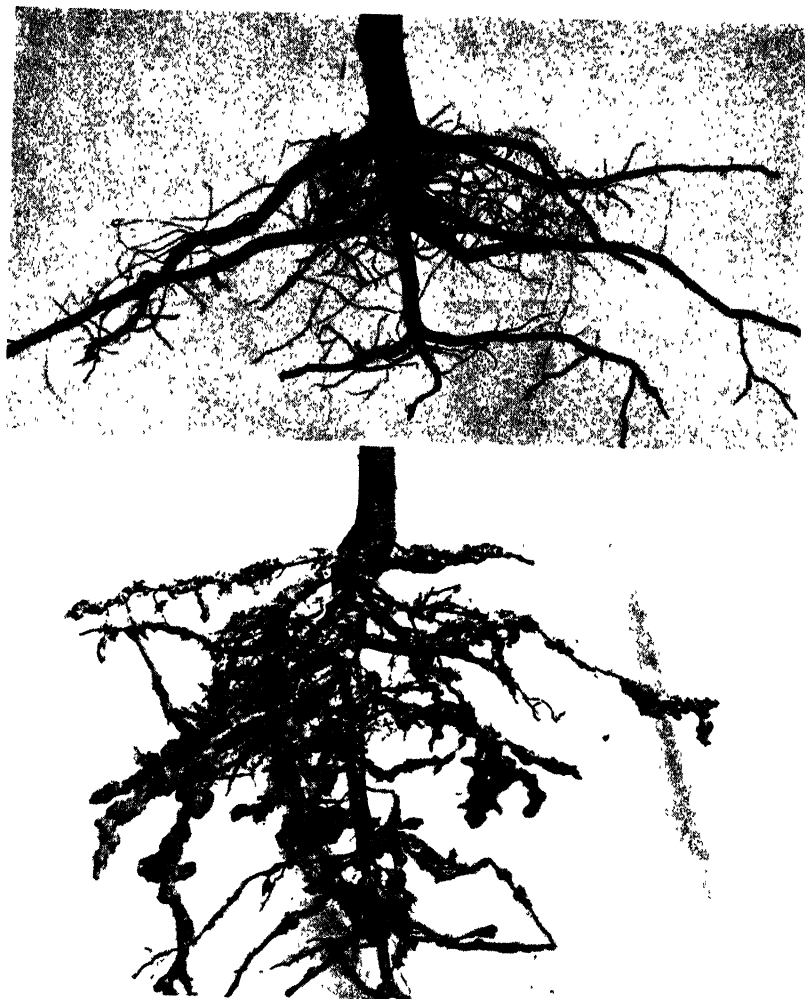


FIG. 6. Above, nursery tree of F.P.I. 63850 (Shalil), resistant to root-knot; below, nursery tree on "natural" rootstock, severely affected by root-knot. Photographed at Fort Valley, Georgia, February 11, 1932.

borne large crops of fruit for their age, but the rootstock employed is moderately susceptible to root-knot and is not suitable for nursery culture on nematode-infested land.

F. P. I. 41498:—Early Hiley peach trees propagated on understocks of F.P.I. 41498, in orchard No. 3, grew rapidly and were very productive (Fig. 1). However, seedling nursery trees of this introduction number grown on nematode-infested soil were severely affected by root-knot.

"Natural."—Seed from the naturalized peach of the southeastern mountain areas has been used as the standard understock for peach trees in the South for many years. Peach varieties worked on these "natural" rootstocks may produce uniform trees of excellent vigor (Fig. 3), but the roots are very susceptible to root-knot and this stock is not suitable for use on land where nematode infestation is severe.

F. P. I. 63850 (Shalil).—Seeds of the Shalil peach, obtained from India in 1913, were grown at the United States Plant Introduction Garden, Chico, California. Some of the resulting seedlings appeared to be worthy of propagation and were assigned inventory numbers. In September, 1927, the writer became interested in F.P.I. 63850, then a large bearing tree (Fig. 5).

In late winter, 1928, Elberta nursery trees budded on Shalil (63850) seedling understocks were obtained from the Plant Introduction Garden at Chico and were planted in orchard No. 2 at Fort Valley, Georgia. By 1931 there was a notable difference in height and vigor among trees on different rootstocks, and trees on the Shalil rootstock were among the best in the orchard. A similar result was obtained with 44 trees of Early Hiley on Shalil (63850) understocks planted in orchard No. 3 in late winter of 1931. These trees are among the most vigorous and productive in this orchard, where nine different rootstocks are under test (Fig. 4).

In addition to being a vigorous rootstock, the Shalil (63850) used in these tests has shown complete resistance to root-knot in heavily infested soils (Fig. 6). Similar results on nematode resistance with Shalil were reported in California by Tufts and Day (1, 2). It is regarded as a very promising selection for general use by nurserymen in securing vigorous, nematode-resistant seedling stock for budding to the commercial peach varieties.

Although the Shalil (63850) grows vigorously at Fort Valley, Georgia, the nonbudded trees do not behave normally throughout the year in this climate. The trees are leafy long after autumn leaf-fall has taken place in other peach varieties; complete defoliation may not occur before mid-January. The trees usually open some flower buds during each month of the fall and winter, which flowers are lost from subsequent frost or freezing. This cuts down the fruit crop appreciably, although a fair crop may be borne in some years.

From our experience with Shalil in the tests here reported, it is believed that orchards for seed production should be grown in a climate where fall and winter temperatures are lower than those experienced at Fort Valley, Georgia.

This is further indicated by a consideration of the climatic conditions in the area from which the variety was obtained. The records of the original importation of Shalil seeds, as furnished by the Division of Plant Exploration and Introduction, Bureau of Plant Industry, United States Department of Agriculture, show that it was obtained from Kurram Valley, North West Frontier Province, India, at about 5,600 feet elevation.

In a letter D. V. Karmarkar, Senior Research Assistant, Office of the Cold Storage Research Scheme, G. F. E. Station, Kirkee, India,

quotes the Director of Agriculture of Allied Departments, North West Frontier Province, India, as follows:

"Shalil is found cultivated in the Upper Kurram Valley along the white mountain. The area lies between 33.45 and 34 North. The altitude of this locality is 4,600 to 6,000 feet. Nearly three-fourths of its annual rain is obtained during winter and mostly in the form of snow. The lowest temperature recorded last winter was 13.

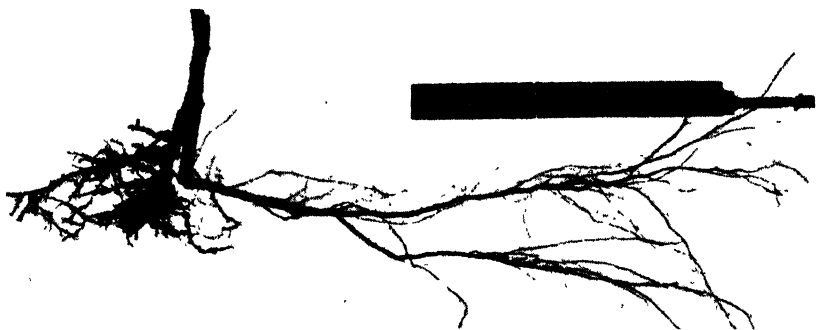


FIG. 7. Nursery peach tree propagated by grafting scion of Early Hiley on root-piece of F.P.I. 61302. Showing: left, scion of Early Hiley severely affected by root-knot; right, nematode-resistant roots of F.P.I. 61302. Photographed at Fort Valley, Georgia, November 23, 1932.

"The Shalil tree is found to do well under the above climatic conditions, [where it] enters its rest period completely and [remains dormant] from about the first week in November until about the first week in April. In short, the winter where Shalil thrives is little milder than the winter at Salt Lake City, Utah (U. S. A.)."

Further observations will be necessary before it can be determined to what extent resistance to root-knot may be dominant in crosses between Shalil and other varieties. As a safeguard, it would be preferable to propagate Shalil trees for seed production by using bud or scion wood that is in direct line of clonal propagation from the original tree of F.P.I. 63850 at Chico, California.

F.P.I. 61302.—Elberta nursery trees propagated at the United States Plant Introduction Garden, Chico, California, by budding on seedling understocks of F.P.I. 61302 (a cross between Bolivian Cling and Quetta nectarine) were received in January, 1928. One hundred of these trees were planted in one test orchard and 30 in another orchard. In both locations these trees made unusually vigorous growth, and by the end of the third year were from 1 to 3 feet taller than trees on any other rootstock except Shalil (63850). Upon examination, the roots of F.P.I. 61302 were found to be free from nematodes, whereas "natural" and other nematode-susceptible roots in the same orchards were galled by root-knot. Extensive clonal propagation was made in January, 1931, by root-pruning the trees on the F.P.I. 61302 root-

stock and grafting scions of the Early Hiley on the root pieces. The piece-root grafts were planted in soil heavily infested by the nematode, where they developed into very vigorous nursery trees during the same year. When the nursery trees were dug, in the fall of that year, it was found that the roots of F.P.I. 61302 were entirely free from root-knot.

Clonal propagation of F.P.I. 61302 rootstocks was repeated in

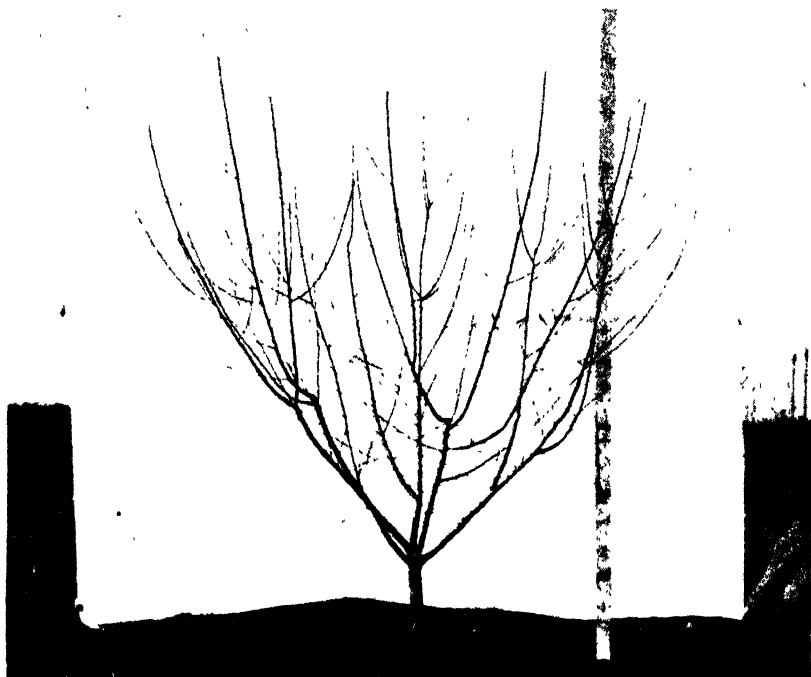


FIG. 8. Early Hiley peach tree, 11 feet tall, on rootstock of F.P.I. 61302. At completion of 2 years' growth in orchard. Photographed at Fort Valley, Georgia, December 21, 1934.

several succeeding years, and in all cases these roots were completely resistant to nematodes. In some nursery trees so propagated, the Early Hiley scions put out roots and the latter were severely affected by root-knot (Fig. 7).

During 1931 to 1933, about 4,000 trees of the Early Hiley peach variety, propagated by grafting scions on root pieces of F.P.I. 61302, were planted in commercial orchards at Fort Valley, Georgia. All of these orchards are now in bearing; the trees are of excellent vigor, produce heavy crops for their age, and the understocks have remained free from root-knot (Fig. 8).

EFFECT OF ROOTSTOCKS ON BLOOMING DATES

In rootstock orchard No. 3, planted in January, 1931, at one end of each row is an unbudded seedling of the species or variety used

as an understock for Early Hiley trees in the remainder of the row. In 1934, when the Early Hiley trees bore their first full crop of flower buds, comparative observations on spring growth development of the Early Hiley and the seedling trees were made.

The blooming response of the Early Hiley variety was very little influenced by the rootstock on which the trees were grown. On March 28, 1934, the trees were in the same stage of blooming on Arlington Farm No. 21868, almond, apricot, *Prunus davidiana*, *P. hortulana*, *P. mume* and F.P.I. 63850. F.P.I. 41498 and Natural apparently caused a slightly delayed blooming response. Earliness or lateness in blooming and leafing of a rootstock species or variety did not correspondingly influence the blooming stage of Early Hiley trees on these rootstocks. The Early Hiley trees on the various kinds of rootstocks have bloomed in keeping with the response of this variety to environmental conditions, and the character of the rootstock has been of little importance. No significant differences in fruit ripening dates have been noted in Early Hiley trees on one rootstock as compared with another.

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Methods of Strawberry Breeding in Louisiana

By JULIAN C. MILLER, *Louisiana State University, Baton Rouge, La.*

LOUISIANA leads all other states in the production and car-load shipment of strawberries. The average annual production is 3,000 cars, valued at \$6,500,000.00. The Klondike is by far the leading variety for this district and it has been estimated that 95 per cent of all plantings are of this variety. The next variety of any importance is the Missionary, which is planted primarily for very early shipment. No other commercial varieties yet tested seem to be suited to conditions in south Louisiana.

While the Klondike has many excellent qualities which place it first among the American varieties of strawberries, it has at least a few characters that the Louisiana growers would like to see improved upon. The most important improvements that are desired are (a) a variety which is more resistant to the two major diseases in Louisiana, namely, Leaf Spot (*Mycosphaerella fragariae*) and Scorch (*Diplocarpon earliana*), and (b) a variety which is sweeter than the Klondike but still retains the shipping qualities and other excellent characters of this standard variety.

After preliminary study, the following methods of handling the breeding materials were adopted: All varieties known to have any resistance to either of the above diseases were collected. So far, the following varieties have been used as parental materials: Klondike, Missionary, Aroma, Howard 17 (Premier), and Blakemore. Crosses between the better seedlings and back-crosses to parents have also been made. The crosses are usually made during April and May. The seed are cleaned by fermenting, dried, and placed in cold storage until the following February, when they are planted in flats and placed in a greenhouse or hothed for germination. They are allowed to remain in flats until three true leaves develop and are then transplanted to 3 inch pots and placed in an open bed, plunging the pots in the soil to the rim. They are allowed to remain there until about the first of June, when the most vigorous and disease-free seedlings are removed to nursery plots. Here the seedlings are planted 6 feet apart on level rows which are 6 feet apart. They are clean-cultivated throughout the summer. Soon after setting in June, many of the plants begin to make runners and new plants, and continue until stopped by the very cool weather of November and December. By this time from 250 to 500 plants have developed from the more vigorous seedlings. In contrast, there are always a number of seedlings that never produce any, or but a few, runner plants. These plants are allowed to remain in the nursery for 1 year, where they are studied for other characters.

For the first year's fruiting test, 40 plants of each of the better seedlings are set 1 foot apart in 3½-foot rows for field study both at the Louisiana State University and at the Fruit and Truck Experiment Station at Hammond.

To insure possible infection with the two diseases, Leaf Spot and Scorch, the seedlings are sprayed at monthly intervals with a spore suspension in water, from the time they have true leaves until after

the fruiting period the following spring. In this manner the resistant seedlings are located. The spore solution is made by picking the diseased leaves from susceptible varieties, and dampening them. They are then placed in layers several inches thick between moist cloths and kept at room temperature for 48 hours. The leaves are then placed in clean water, rubbed together, and the solution strained through a fine wire gauze into the spray tank. It is sprayed upon the plants immediately. Precaution is taken to get the spray under the leaves as well as on the top surface.

Most of the seedlings are eliminated during the first year, only 2 to 5 per cent being saved for a second year's study. The second year's investigation consists of making yield studies, quality analyses, co-operative field studies with growers, and trial shipment of the most promising ones. At the end of the second year it is possible to make a further elimination, keeping the best for further trials and comparisons.

Strawberries are very much like corn in that most varieties are at their best within definite regions. To make rapid progress by breeding, the work should be done within the general area or under climatic conditions similar to those where the plants are to be grown.

Inheritance of Size of Plants and Resistance to Rhizoctonia in Strawberries

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ABSTRACT

This paper will be published in full in the *Journal of Agricultural Research*.

THIS paper discusses the results of measurements of plants of strawberry seedlings which were grown at the Oregon Experiment Station, Corvallis, Oregon. The measurements involve more than 28,000 plants of about 250 different crosses. These measurements show that crosses involving parents which are largely of *Fragaria chiloensis* parentage generally give the largest plants. Ettersburg 121 was used to a considerable extent as a parent and the resulting seedling plants generally were of large size. Ettersburg 121 shows many of the characteristics of *F. chiloensis*. Crosses between varieties not of *F. chiloensis* parentage generally gave seedlings of smaller size. Soil which was infected with rhizoctonia had considerable influence upon percentage of large plants resulting from the different crosses. The influence was less marked in seedlings from parents largely of *F. chiloensis* parentage.

The Influence of Spacing Strawberry Plants on Leaf Development¹

By E. P. CHRISTOPHER, *Rhode Island State College, Kingston, R. I.*

THE results of Darrow and Dearing (1) from strawberry spacing experiments in North Carolina, suggest the need for some changes in strawberry cultural methods in Rhode Island. In order to check their data under our conditions, and to determine the best practice for our growers to follow, a spacing experiment was started at Kingston, Rhode Island, in April, 1936. A practically level area, 216 feet north and south by 80 feet east and west, was available. This ground had a cover crop in 1935, but lay fallow during the winter. One hundred and forty plats were laid out. These were 30 feet long by 3 feet wide, and ran north and south. A space of 1 foot was left between the ends of adjoining plats. A 1 foot aisle was maintained between adjacent plats.

Plants of Howard 17 and Dorsett varieties were set out on the 13th and 14th of April, in alternating rows according to the planting plan for the 14 treatments given in Table I. There were five plats of each treatment distributed over the field in an effort to overcome any differences in soil (Fig. 1). A few days before planting, 3¼ pounds of a 5-10-5 fertilizer was applied to each plat. Because of a very cold spell just after planting, many plants were injured and had to be reset. Plants were replaced, as they showed injury, until May 12, at which

TABLE I—TREATMENTS AND PLANTING PLAN OF RHODE ISLAND STRAWBERRY SPACING EXPERIMENT

Row No.	Spacing of Mother Plants (Inches)	Number Mother Plants per Plat	Spacing Distance of Runner Plants (Inches)	Planned Number Runner Plants per Mother Plant	Planned Runner Plants per 30-Foot Plat
<i>Matted Row</i>					
1	18	20	None	56.1*	1,123
2	24	15	None	52.7*	790
3	30	12	None	79.5*	954
4	36	10	None	87.2*	872
<i>Spaced Row</i>					
5	18	20	6	18.0	360
6	18	20	8	10.1	202
7	18	20	10	6.5	129
8	24	15	6	24.0	360
9	24	15	8	13.5	202
10	24	15	10	8.6	129
11	30	12	6	30.0	360
12	30	12	8	16.9	202
13	30	12	10	10.8	129
14	24	15	13	5.0	75

*Number runner plants per mother plant by actual count in matted row treatments.

¹Presented by permission of the Director of Research as Contribution No. 501 of the Rhode Island Agricultural Experiment Station.

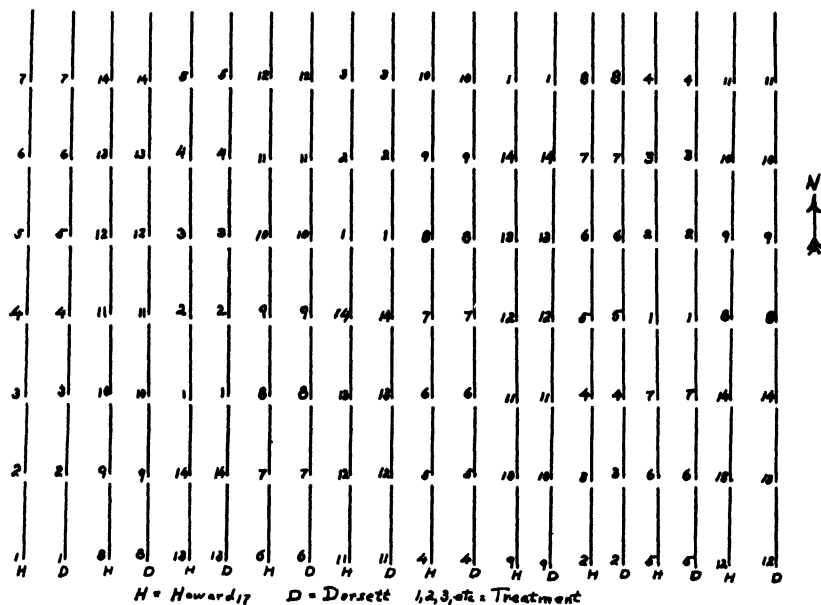


FIG. 1. Plot arrangement of strawberry spacing experiment in Rhode Island.

time all plats appeared to be as nearly equal as it was possible to get them. Blossoms were picked off as soon as they appeared.

The first runners were noted June 10, and the first runner plants set out about June 25. Runner plants were allowed to develop naturally until the maximum number for any given plant had been formed, after which time all other runners were removed. An effort was made to distribute the runner plants reasonably well, but no effort was made to place them exactly, except in Treatment 14. If a given mother plant was allowed 18 runner plants, spaced 6 inches apart, an average of 6 inches was sought, but one individual plant might be 5 inches and another 7 inches from its neighbor. It was much simpler and perhaps more nearly commercially practical to space in this way. In the matted row plots all runners were allowed to root with no attempt to space them.

The plants made a good growth in most instances, and marked differences in leaf number and size were apparent. Sproat, Darrow and Beaumont (2), and Darrow and Dearing (1), found a marked correlation between leaf area and fruit production. Therefore, the leaf development secured in our plats this summer should be a rough index of the crop yield which may be expected next June. In late October and early November, a light wooden frame, exactly 1 foot wide and 4 feet long, inside measurements, was placed over each plat in four evenly spaced places. All of the leaves on each plant found within the frame were counted, and the number recorded. The four samples thus secured were combined to determine the average number of leaves per plant for the plat. The results from the five plats in each treatment were combined to secure an average for the treatment (Table II).

The average number of leaves per plant in the first four treatments, (all matted row) ranged from 4.68 to 5.92, as compared to Treatment 14, where the average for Howard 17 was 23.62, and for Dorsett, 17.87. With one exception, no matter what the original planting distance of mother plants was, runners spaced at the greater distance had more leaves per runner plant. With mother plants set 18 inches apart (Treatments 5, 6, and 7), a marked increase in leaf number was secured when runners were set 8 inches apart, instead of 6 inches, but not as great an increase occurred where the spacing was increased to 10 inches. A similar response was noted when the mother plants were set 30 inches apart. When mother plants were set 24 inches apart, a marked increase in leaf number was noted with each increase in runner spacing. When the number of runner plants developed by each mother plant is plotted against the average number of leaves per plant (Fig. 2), it will be noted that there is a close inverse relationship.

TABLE II—AVERAGE NUMBER AND AREA OF LEAVES PER PLANT IN STRAWBERRY SPACING EXPERIMENT

Treatment	Spacing Distance (Inches)	Howard 17			Dorsett		
		Average Number Leaves per Plant	Average Area per Leaf (Sq. In.)	Leaf Area per Plant (Sq. In.)	Average Number Leaves per Plant	Average Area per Leaf (Sq. In.)	Leaf Area per Plant (Sq. In.)
1	Matted row	4.91	4.69	23.05	5.27	4.55	23.99
2	Matted row	4.90	6.85	33.55	4.96	6.84	33.92
3	Matted row	5.92	3.83	22.68	4.68	6.29	29.42
4	Matted row	5.08	5.31	26.99	4.89	5.21	25.49
5	6	8.16	9.10	74.22	7.89	8.93	70.47
6	8	15.13	8.14	123.13	16.23	9.30	150.87
7	10	14.55	10.41	151.44	17.39	12.62	219.47
8	6	7.51	7.31	54.91	7.62	9.64	73.47
9	8	10.99	7.35	80.78	10.82	13.60	147.12
10	10	16.61	7.57	125.76	17.61	11.42	201.10
11	6	6.94	6.75	46.86	6.89	8.87	61.10
12	8	9.39	8.78	82.46	9.72	10.55	102.52
13	10	10.13	8.23	83.40	10.86	10.46	113.58
14	13	23.62	8.59	202.98	17.87	15.57	278.32

The greater the distance between mother plants, the longer time it will ordinarily take to secure all of the necessary runner plants at a given spacing distance. Because of the later development of some of the runners, it would be reasonable to expect a somewhat smaller number of leaves on runners equally spaced, but developing from mother plants set further apart. In all cases except Treatment 10, where the plants were set 24 inches apart, and spaced 10 inches apart, this relationship holds. Earliness of development appears to be a factor in determining the number of leaves per plant.

In the manufacture of food through photosynthesis, the number of leaves per plant would not be expected to be as important as the total leaf surface per plant. The frames used in counting the number of leaves per plant were placed across each plat, and all leaves within the frame were cut off. All stems were removed, and the dry weight of each sample determined. The dry weight of a number of leaves of known area

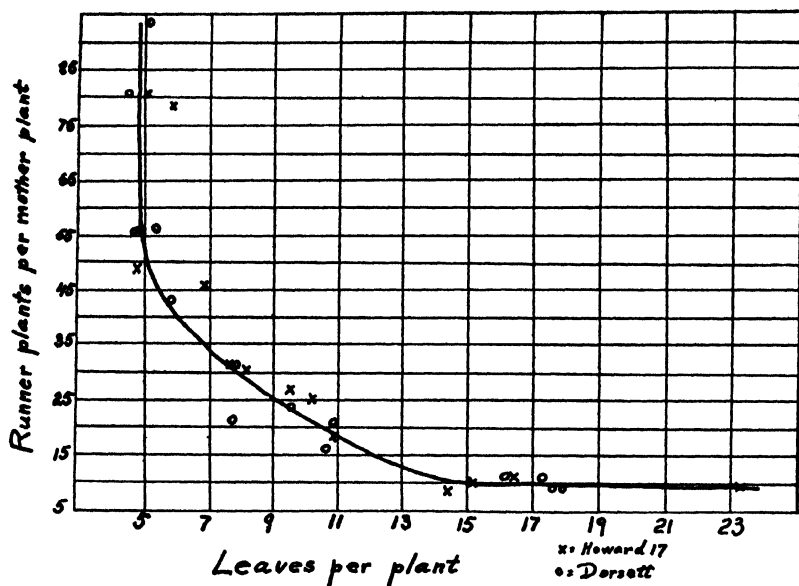


FIG. 2. Relationship of number of runner plants per mother plant set to number of leaves per plant on Howard 17 and Dorsett strawberries. (Free hand curve.)

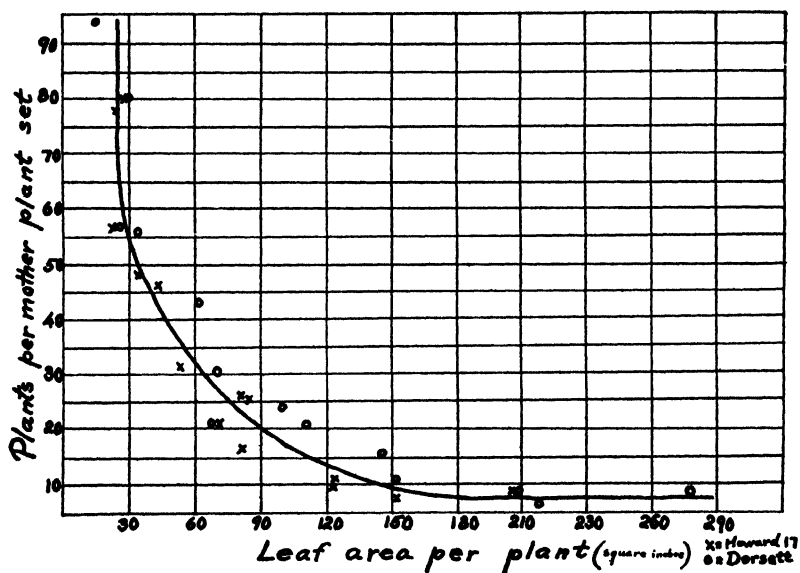


FIG. 3. Relationship of plants per mother plant set to leaf area per plant on Howard 17 and Dorsett strawberries. (Free hand curve.)

was determined, and from the figures available, the average leaf area per plant was determined. The relationship between the number of plants for each mother plant set, and the average leaf area per plant is shown in Fig. 3. It will be noted that the greater the number of plants per mother plant, the smaller the leaf area per plant. The large number of leaves on the well spaced plants does not necessarily result in a reduction in the size of each leaf. The matted row treatments have the smallest number of leaves per plant, the smallest average leaf size, and the smallest leaf area per plant. Calculations of the total leaf area per plat, show quite a variation, but the matted row treatments are below average.

From these data, it would appear that under the growing conditions during the 1936 season at Kingston, Rhode Island, the production of large, well developed plants, capable of heavy yields (1) was markedly favored by spacing.

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Early Growth of Strawberry Plants Resulting From Several Methods of Handling Before Setting

By M. B. HOFFMAN, *Cornell University, Ithaca, N. Y.*

MANY of the strawberry growers in the Hudson Valley section of New York State purchase their plants from nurseries located in Delaware and eastern Maryland. The planting season in the Hudson Valley section is about 3 weeks to 1 month later than in the area where the plants are grown. In placing orders for plants the growers usually estimate as near as possible the date on which the plants can be set in the field and request delivery at that time in an effort to avoid the laborious task of heeling-in strawberry plants. Naturally, many of the plants received have already made appreciable amounts of growth in the more southern sections before they are dug for shipment.

During the past several years, strawberry growers in the Hudson Valley section have experienced considerable losses from strawberry "root-rot" or "black-root" injury. The losses have been especially heavy shortly after the plants are set in the field. Fifty to 80 per cent of the plants died in some of the new plantings made in the spring of 1936. These plants died in fields belonging to experienced growers and the losses could not be attributed to a careless job of setting plants.

Roberts (2) has pointed out that much of the "black-root" troubles of strawberry plants in Wisconsin is initiated by freezing of the tissues. His work indicates that plants should be mulched in that state before the temperature falls to about 20 degrees F or the plant crowns may be injured. There was unmistakable evidence of winter injury in many of the plants purchased by Hudson Valley strawberry growers this past spring. The injury showed as internal browning of the crown, especially near the base of the stem and varying degrees of discoloration of the roots.

Many nurserymen in the Middle Atlantic States do not make a practice of mulching those fields which are used for propagating purposes. They probably have not realized that occasional injury from low temperatures occurs, although they have set new fields of their own with injured plants. Transplanting in those sections is done before much active growth takes place. Under such conditions injured plants may show a rapid recovery and make a satisfactory growth in early season.

If, however, transplanting is delayed until a large foliage has developed, it is to be expected that the mortality rate would be higher. With a large leaf area, transpiration may be responsible for an excessive loss of moisture from the plant. Under such conditions the roots may not be able to supply sufficient moisture to keep the plants alive. The root system is reduced in digging the plants and the growth of roots is not as rapid with winter injured plants as it is with uninjured plants. Much of the stored food has been used for top and root growth before the plants are dug while other quantities in the winter-killed tissue is not available for growth.

The serious losses that have occurred in some of the new plantings in New York State may have been due to a combination of factors,

namely, winter injury and the active growing condition of the plants at the time they are received from the nursery. An experimental planting was made in the Hudson Valley area in the spring of 1936 for the purpose of studying this problem. Different planting dates and different methods of handling the plants before planting were used in the several plots. All plants were obtained from one nursery located on the eastern shore of Maryland. The layout was as follows:

Plot 1. Plants received March 28. Left in shipping moss which was kept moist. Planted April 9.

Plot 2. Plants received March 28. Heeled-in March 29. Planted April 9.

Plot 3. Plants received March 28. Placed in cold storage 31 degrees F, March 28. Removed from storage and planted April 14.

Plot 4. Plants received March 28. Placed in cold storage 31 degrees F, March 28. Removed from storage and planted May 7.

Plot 5. Plants received April 14. Planted immediately.

Plot 6. Plants received May 7. Planted immediately.

The plants received March 28 were just beginning to show signs of growth. The object of getting plants at this time was to obtain dormant plants and hold them in this condition until the land could be prepared for planting. Most of the strawberries grown in this section of New York State are set about April 20 to May 1. The shipments of plants which arrived on April 14 and May 7 were intended to coincide with the earliest and latest dates that the growers normally receive plants. The plants received on April 14 showed considerable new growth while the flower clusters on those arriving May 7 had developed to full bloom. The appearance of all plants was very unsatisfactory. Many of the roots were black and a large per cent of the plants probably would have died if extreme care had not been used in transplanting.

On July 2 some differences in growth of the plants in the various plots were noticed. The data recorded in Table I were taken at this time. The plant growth on plots 1, 2, 3, and 5 was considered very good for this season of the year. Plot 3 was the best one of the entire planting. This could be told merely by inspection at any time during the summer. The plants used on plot 3 were received March 28 and held, without

TABLE I—GROWTH OF STRAWBERRY PLANTS SET ON DIFFERENT DATES AND HANDLED IN DIFFERENT WAYS BEFORE PLANTING
Average for 20 plants—July 2, 1936

Plot	Average Area Largest Leaflet on Plant (Square Inches)	Average Number Leaves per Plant	Average Number Runners per Plant	Average Number Runner Plants (per Plant)	Plants Dead (Per Cent)
1	5.1	8.2	4.9	1.5	0.4
2	5.3	8.0	5.7	1.7	1.3
3	5.9	9.0	6.5	2.2	0.3
4	4.2	5.9	1.9	0.3	1.1
5	5.8	6.7	5.4	1.6	1.6
6	3.9	5.4	1.6	0.0	5.6

unpacking, in cold storage at 31 degrees F until April 14 when they were transplanted. This is a most convenient method of handling plants in communities where cold storage facilities are available and it assures one of dormant plants if the planting date is delayed for any reason.

Plots 4 and 6 were set on the same day, May 7. Plot 4 was the better of the two. The difference in these two plots was due to the difference in the stage of growth of the plants at the time they were set.

Sproat, Darrow, and Beaumont (1) have shown that there is a very close relationship between leaf area of the plant and the production of berries. The maximum leaf area was developed in this experiment when dormant plants were used and when the transplanting was done early in the season. It is possible that these practices which favor the greatest leaf development might also lessen the "root-rot" troubles.

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The Effects of Summer and Spring Applications of Fertilizers On the Fruit Production of the Strawberry

By J. H. LONG, *University of Missouri, Columbia, Mo.*

ABSTRACT

This material will be published in full in a research bulletin by the Missouri Agricultural Experiment Station.

A SERIES of experiments was started in 1929 in an attempt to modify the fertilization program of strawberry plants growing in the field. Nitrogen, phosphorus, and potassium, each alone, and in combinations were applied in the field in early August of each year to triplicated plots. An additional application was made in early spring as soon as conditions would permit. In almost every case where the summer addition of fertilizers was made more flowers formed and a greater percentage of fruits set than on check plots. Particularly is this true of combinations of fertilizers.

The spring use of fertilizers in addition to the summer treatment proved of little value, serving principally to cause a few more flowers to set their fruits, an increased leaf area, and poor ripening.

The use of fertilizers in the summer or early autumn proved most valuable, in that more flowers were formed, leaf area was increased with a consequent greater storage of nitrogen and carbohydrates upon which fruit production may depend.

The Response of Strawberries to Irrigation in a Dry Harvest Season

By F. E. STAEBNER, *U. S. Department of Agriculture,
Washington, D. C.*

THE irrigation investigation upon which this report is based was conducted in 1936 cooperatively by the Division of Drainage, Bureau of Agricultural Engineering, and the Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture; the Horticultural Department of the University of Maryland; and the W. F. Allen Co., owners of the experimental tract. The investigation had been started prior to 1936 by the last two of the cooperating agencies. The tract is located on the Eastern Shore of Maryland.

The soil on which the experiments were conducted is classified by the Soil Survey as Sassafras loamy sand. The wilting coefficient of this soil at a depth of 9 inches as determined in 1935 by the University of Maryland was 2.8.

The tract of land used for these experiments was laid off into 18 plots each 45 feet long (Fig. 1), and planted in five or six rows. The plots containing five rows were planted in one row each of the five following varieties: Blakemore, Catskill, Dorsett, Fairfax, and Premier, and the six row plots, of which there were six, contained in addition the variety known as Big Joe. The 18 plots were divided by a 3-foot

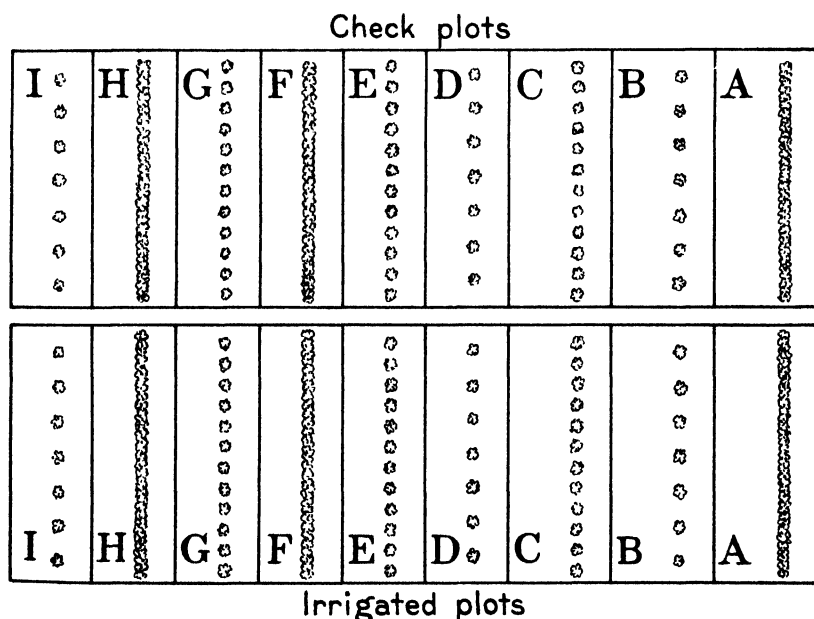


FIG. 1. Arrangement of plots, showing plots with plants spaced at 11-inch and 7-inch intervals and grown in matted rows.

path into two groups of nine plots each, so the plots on one side of the path, reserved as check plots, were the duplicates of those on the other side, which were irrigated.

The nine watered plots were again divided into three groups of three plots each, of which one plot in each group was composed of matted rows, one plot had the plants spaced at 7-inch intervals, and one at 11-inch intervals. Irrigated plots A, B, and C, were scheduled for an application of $\frac{1}{2}$ inch depth of irrigation water each time they were watered; irrigated plots D, E, and F, were scheduled for $\frac{3}{4}$ inch and plots G, H, and I, for 1 inch. For the period of the fruiting season arrangements were made to irrigate twice a week in case of continued drouth.

Owing to the plot arrangement there was a check row for each irrigated row, the check row being an extension of the corresponding irrigated row but broken by the path previously mentioned.

During the harvest season soil samples were taken twice a week in five plots, namely, check plots A and D and irrigated plots B, D, and I. All of these were plots with 11-inch spaced rows, except check plot A, so the data is believed to cover the average soil moisture condition. Check plot A was a matted row plot from which the thickly growing plants could be expected to withdraw the soil moisture with relatively great rapidity, and so was expected to indicate the extreme of dry conditions. Samples were taken by means of a King soil tube to four different depths, namely 0 to 3 inches, 3 to 6 inches, 9 to 12 inches, and 15 to 18 inches. There were three bore holes put down in each plot at each sampling, one in the Catskill row, one in the Dorsett row, and one in the Premier row. The samples from the four different depths of the three bore holes of each plot were combined by layers to give four composite samples. These samples were dried in an electric oven, and the soil moisture content as computed, was used as a guide in applying the irrigation at the next subsequent semi-weekly irrigating date.

The basis of applying water was as follows: if the soil moisture in the second layer, namely, the 3 to 6 inch depth, in irrigated plot B on the previous semi-weekly soil sampling proved to be less than 5 per cent, water to a depth of $\frac{1}{2}$ inch was applied to irrigated plots A, B, and C, unless that amount of rainfall had fallen in the intervening 3 or 4 day period. If the soil moisture in the second depth layer of irrigated plot D proved to be less than 7 per cent at the previous sampling water to a depth of $\frac{3}{4}$ inch was applied to plots D, E, and F, subject to a suitable correction for rainfall, and if the similar moisture content in plot I proved to be less than 9 per cent, water to a depth of 1 inch was applied to plots G, H, and I. All the irrigation water was applied by means of porous hose.

It was the intention to apply no water to the check plot but owing to the extremely dry season it was deemed necessary to water the check plots in order to save plants for future experimentation. Accordingly, during the week of May 18 to 23 one irrigation to a depth of 2 inches was applied to check plots A, B, and C, to 2 rows of plot D, and to $\frac{3}{4}$ of the length of the other rows of the check area. A second irrigation (also 2 inches in depth) was applied on May 25 to 26. Because soil moisture samples were being taken in plot D it seemed desirable that

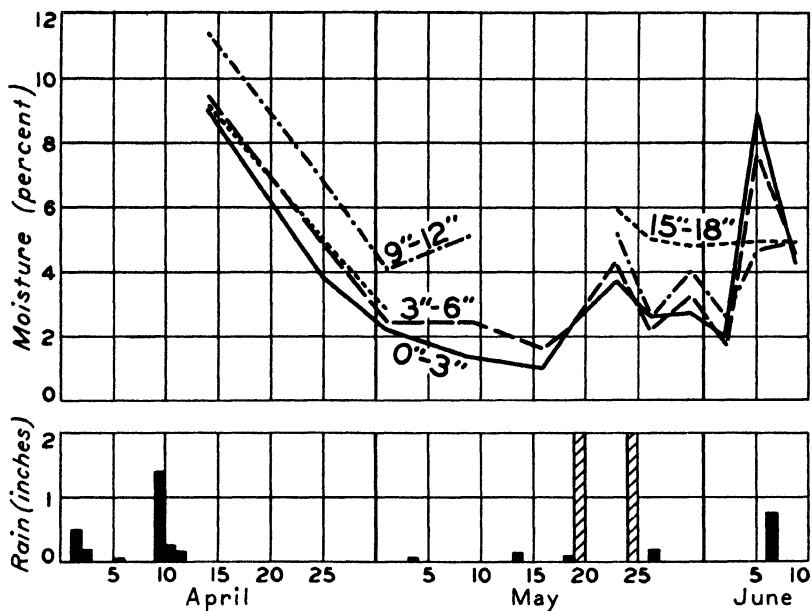


FIG. 2. Moisture percentages in check plot A, also rainfall (solid black lines) and irrigation (shaded lines).

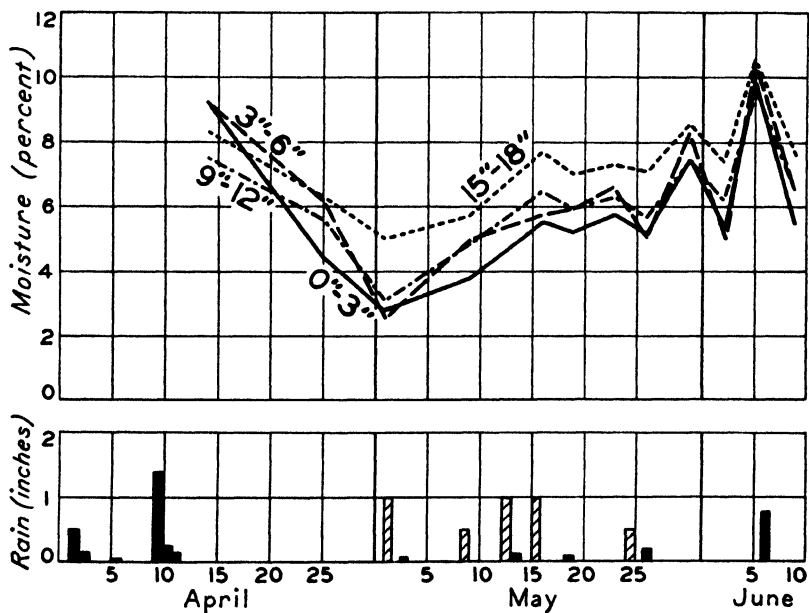


FIG. 3. Moisture percentages in irrigated plot I; also rainfall (solid black lines) and irrigations (shaded lines).

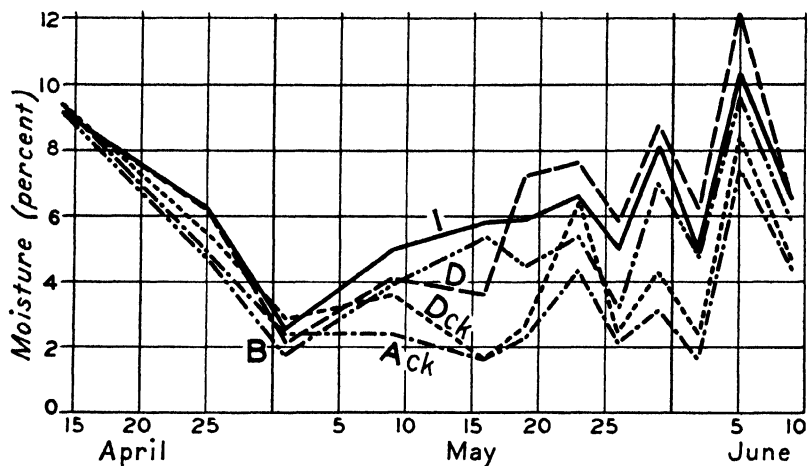


FIG. 4. Moisture percentages found in second layer (3- to 6-inch depth) in all five of the plots in which soil samples were taken.

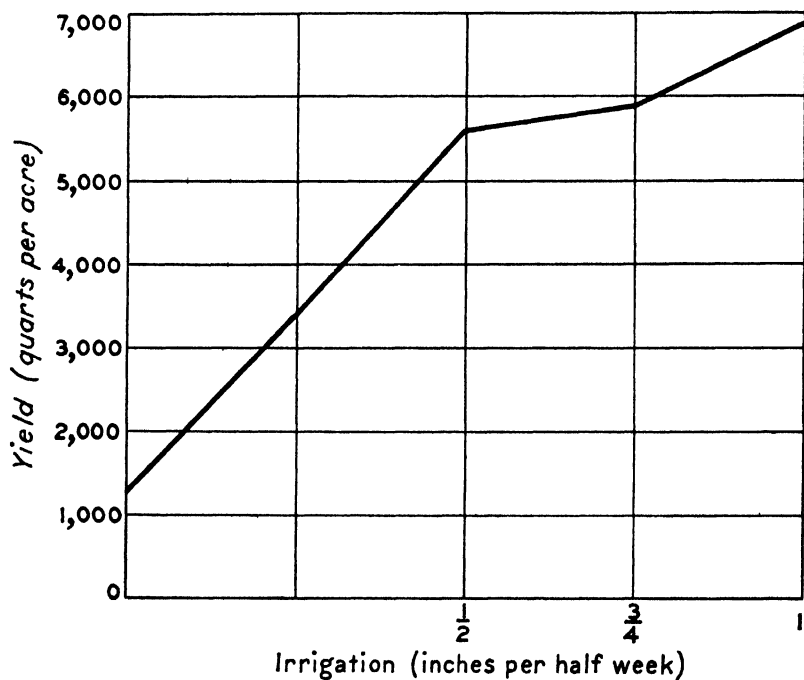


FIG. 5. Graph of strawberry yield plotted against scheduled irrigation applications.

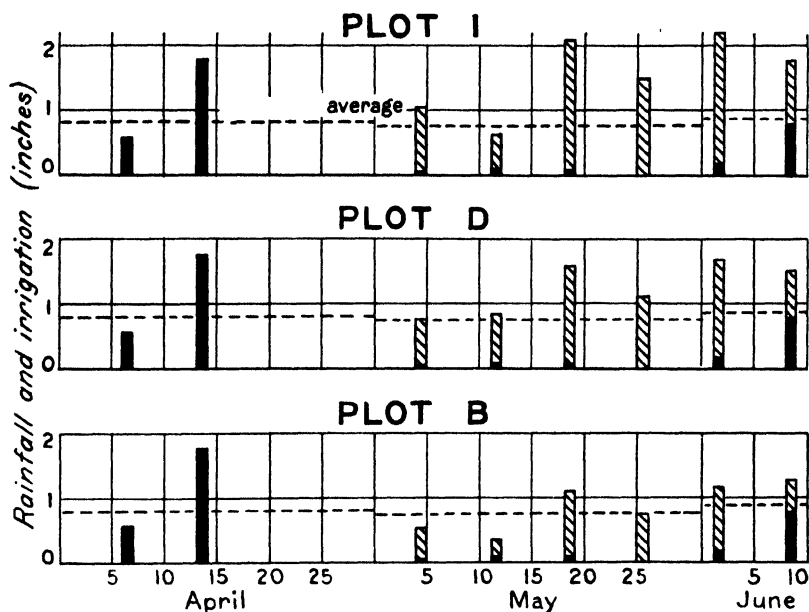


FIG. 6 Inches depth of water per week (rainfall plus irrigation) received by the experimental plot as compared with average rainfall (shown by dashed line).

uniform moisture conditions should be present in all parts of that plot and for that reason a 2 inch depth of irrigation was applied on May 27 to the unwatered quarter of the other three rows of that plot.

The rainfall data reported in this paper was obtained from the records of the Salisbury, Maryland station of the Weather Bureau for the period from April 1 through May 17 and from a rain gauge maintained on the tract by the University of Maryland from May 18 to June 9 inclusive.

The graphs, Figs. 2 and 3, show depths and dates of rainfall and irrigation and soil moisture percentage determinations up to the last picking date for check plot A and irrigated plot I. Check plot A is the one unirrigated matted row plot in which soil moisture determinations were made, and irrigated plot I the most heavily irrigated. As was to be expected the lowest and highest average soil moisture conditions were found in these plots, although the moisture content in check D was as low as in check plot A. This would indicate that strawberry plants at a spacing of 11 inches will take all the soil moisture in a dry time as effectively as the more numerous plants of a matted row planting. The dots show actual determinations of soil moisture on the different dates and the zig-zag lines simply connect the points as determined to help distinguish the moisture percentages of the different depths. As is common in such graphs, some crossing and recrossing of the connecting lines may be noticed. The rainfall depth is indicated by the vertical solid black lines and the irrigation depth by the vertical dashed lines.

The minimum moisture contents found in the second layer (3 to 6 inch depth) of the various plots were as follows: on May 16 in check plot A, 2.6 per cent, on May 19 in check plot D, 1.7 per cent, and on May 1, in irrigated plots B, D, and I, 1.8 per cent, 2.0 per cent, and 2.5 per cent respectively.

Fig. 4 shows in chronological order the changes in moisture content of the second layer (3 to 6 inch depth) of all five of the plots whose moisture was investigated.

The curve shown in Fig. 5 is the graph of strawberry yield plotted against scheduled irrigation applications (*i.e.*, quarts per acre of the commingled yields of all five varieties, excluding the Big Joe variety, plotted against inches depth of scheduled irrigations). The location along the abscissa of the points showing yield from the plots given the 2-inch irrigations is, of course, approximated. This curve indicates that the maximum possible benefit was not obtained. In part, this was probably due to not starting soil moisture sampling and therefore irrigation at a sufficiently early date in this unusually dry season. It is also possible that regardless of the water supply, owing to the hot drying winds that prevailed, the plants would have transpired more rapidly than water absorption occurred and that therefore fruit sizes suffered. At least, however, it shows that the maximum irrigation probably did not supply the maximum moisture that the plants could have used under the most favorable conditions.

In Fig. 6 is shown the inches depth of water received per week by each of the irrigated plots B, D, and I, as compared with the average weekly rainfall. This sheet indicates, in our opinion, that the average rainfall does not provide the maximum possible yield of strawberries in this region. It is also possible that the drying out of the soil prior to the first irrigation caused damage to the plants from which they did not fully recover.

Spacing Studies on Several Strawberry Varieties With and Without Irrigation

By A. L. SCHRADER and I. C. HAUT, *University of Maryland, College Park, Md.*

THESE studies were initiated in the spring of 1935 by J. H. Beaumont and A. L. Schrader with the cooperation of the W. F. Allen Company, Salisbury, Maryland. Irrigation work, reported in another paper in these proceedings, was carried on in 1936 in cooperation with the Division of Drainage, Bureau of Agricultural Engineering and the Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture.

Plots were laid out on a level piece of Sassafras loamy sand, 95 by 150 feet, well prepared for strawberry culture common to the Eastern Maryland section. Eighteen blocks, each containing five single row plots of 45 feet, made possible six replications of five varieties for each of three spacing treatments. The five varieties included Fairfax, Dorsett, Howard 17 (Premier), Catskill, and Blakemore. The three spacing treatments consisted of the matted row system, 7-inch spacing between plants, and 11-inch spacing between plants. Matted rows and "11-inch" rows were planted $3\frac{1}{2}$ feet apart, whereas "7-inch" rows were planted 3 feet apart due to the narrower plant bed produced. Plants were set 22 inches apart in the rows. Varieties were placed at random in each block for each spacing treatment and spacing treatments were arranged at random in three major divisions of the field. The Big Joe variety also was placed as an extra plot in six of the blocks.

Irrigation treatments in 1936, described in another paper (1), included water additions before and during harvest. The actual spacing of Blakemore plants in September, 1935, is shown in Fig. 1. On a single plot

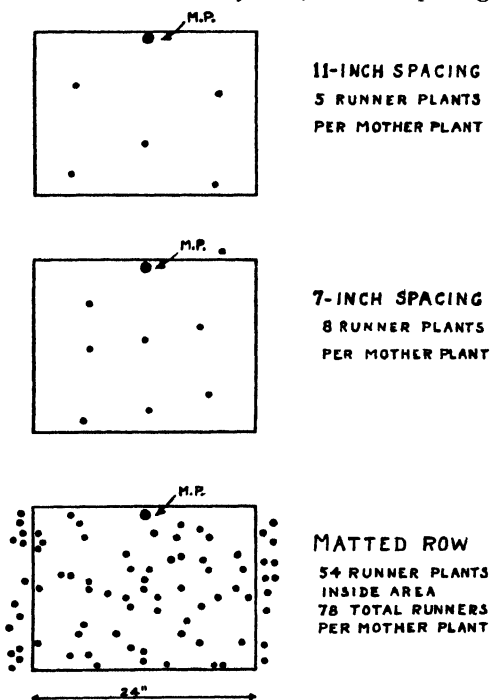


FIG. 1. Distribution of Strawberry Plants in Spacing Experiments, showing actual Placing of Blakemore Plants, 1935 — M.P. = Mother Plant. Blocks contain 3 square feet.



FIG. 2. Comparative development of Blakemore Strawberry Runner Plants under Spacing Treatments. 1 = Matted row; 2= Seven-inch Spacing; 3 = Eleven-inch Spacing. December, 1935.

basis the number of runner plants produced by matted rows was 1500 to 2250 depending on variety; for 7-inch spacing 192 runner plants made a full stand, and for 11-inch spacing, 120 plants. The season of

TABLE I—YIELD OF STRAWBERRIES AS INFLUENCED BY PLANT SPACING AND IRRIGATION

Treatment	Matted Row	7 Inch Spacing	11 inch Spacing	Average
<i>Yield of No. 1 Berries (Quarts per Acre)</i>				
No irrigation	179	418	828	475
Irrigation at harvest	608	1,652	2,053	1,437
$\frac{1}{4}$ inch irrigation weekly	1,798	3,519	2,943	2,754
$\frac{3}{4}$ inch irrigation weekly	1,916	3,494	3,678	3,029
1 inch irrigation weekly	2,691	4,199	4,102	3,664
Average	1,438	2,656	2,721	
<i>Total Yield (Quarts per Acre)</i>				
No irrigation	805	1,342	1,773	1,306
Irrigation at harvest	1,814	4,006	4,392	3,403
$\frac{1}{4}$ inch irrigation weekly	4,562	6,690	5,617	5,623
$\frac{3}{4}$ inch irrigation weekly	4,772	6,456	6,486	5,905
1 inch irrigation weekly	5,841	7,391	7,346	6,859
Average	3,559	5,177	5,123	

TABLE II—NUMBER OF BERRIES PER PLOT (45 FOOT ROW) AS INFLUENCED BY PLANT SPACING AND IRRIGATION (AVERAGE OF FIVE VARIETIES)

Treatment	Matted Row	7-inch Spacing	11-inch Spacing	Average
<i>No. 1 Berries (Quarts per Acre)</i>				
No irrigation . . .	83	222	300	202
Irrigation at harvest	212	586	764	512
$\frac{1}{4}$ inch irrigation weekly	806	1,216	1,208	1,077
$\frac{3}{4}$ inch irrigation weekly	812	1,110	1,341	1,088
1 inch irrigation weekly	1,155	1,223	1,574	1,317
Average . . .	614	871	1,017	
<i>Total Berry Number</i>				
No irrigation . . .	901	1,178	1,549	1,209
Irrigation at harvest	1,724	2,476	3,226	2,475
$\frac{1}{4}$ inch irrigation weekly	3,734	3,402	3,459	3,532
$\frac{3}{4}$ inch irrigation weekly	3,866	3,482	3,716	3,688
1 inch irrigation weekly	4,256	3,642	4,077	3,992
Average . . .	2,896	2,836	3,205	
(Average of Five Varieties)				

TABLE III—YIELDS OF STRAWBERRIES AS INFLUENCED BY PLANT SPACING AND BY IRRIGATION DURING HARVEST

	Yield of No. 1 Berries (Qts. per Acre)			Total Yield (Qts. per Acre)		No. 1 Berries (Per Cent)	
	No Irrigation	Irrigation	Increase	No Irrigation	Irrigation	No Irrigation	Irrigation
<i>Dorsett</i>							
Matted row . . .	379	908	529	1,380	2,196	27.5	41.3
7 inch spacing . . .	523	2,469	1,946	1,972	4,745	26.5	52.0
11 inch spacing . . .	1,276	3,289	2,013	2,014	5,313	60.6	61.9
<i>Fairfax</i>							
Matted row . . .	345	811	466	1,173	2,083	29.4	38.9
7 inch spacing . . .	1,086	2,370	1,284	1,897	4,166	49.1	56.9
11 inch spacing	1,586	3,042	1,456	3,726	4,756	42.6	64.0
<i>Blakemore</i>							
Matted row . . .	34	216	182	379	1,081	9.0	21.3
7 inch spacing . . .	120	1,055	935	805	4,186	14.9	25.2
11 inch spacing . . .	379	1,012	633	966	4,253	39.2	23.8
<i>Catskill</i>							
Matted row	138	673	535	748	1,645	18.4	40.9
7 inch spacing . . .	201	1,201	1,000	1,075	3,395	18.7	36.3
11 inch spacing	483	1,466	983	1,242	3,623	38.9	40.4
<i>Premier</i>							
Matted row	0	431	431	345	2,065	0.0	20.9
7 inch spacing	161	1,174	1,013	644	3,632	25.0	32.3
11 inch spacing	414	1,455	1,041	826	4,016	50.1	36.2

1935 was very favorable for runner plant development and hence the spaced plant rows were nearly filled in (complete) by September 9, in fact most of the plants were set much earlier. The numbers of plants per square foot of matted row on December, 1935 were as follows: Blakemore 25.2, Premier 20, Dorsett, 17.7, Catskill 16.5 and Fairfax 15. Blakemore formed more late fall runners than the other varieties. Calculated on an acre basis, the matted plots had 370,000 to 621,000 runner plants; the 7-inch plots 61,000 and the 11-inch plots 33,000 runner plants. Thus, it is not difficult to explain the plant differences shown in Fig. 2.

The yield data obtained in 1936 are summarized in part in Tables I, II, III, and IV. Harvest started on May 19 and continued until June 9. All berries were harvested, counted and graded by size for No. 1 berries (above $\frac{3}{4}$ inch). In Table I all varieties are averaged to show

TABLE IV—YIELDS OF STRAWBERRY VARIETIES AS INFLUENCED BY PLANT SPACING

Variety	Matted Row	7-inch Spacing	11-inch Spacing	Average
<i>Yield of No. 1 Berries (Quarts per Acre)</i>				
Dorsett	1,510	3,295	3,397	2,734
Fairfax	2,060	3,054	3,223	2,779
Blakemore.	657	1,660	1,693	1,337
Catskill.....	1,653	2,422	2,753	2,279
Premier.....	1,312	2,851	2,537	2,233
Average....	1,438	2,656	2,721	
<i>Total Yield (Quarts per Acre)</i>				
Dorsett	3,396	5,566	5,189	4,717
Fairfax	4,154	5,510	5,771	5,145
Blakemore.....	2,583	4,754	4,577	3,971
Catskill.....	3,732	4,770	5,244	4,582
Premier.....	3,929	5,283	4,833	4,682
Average....	3,559	5,177	5,123	

the effects of spacing under the various irrigation treatments. Since 7-inch spaced rows were planted only 3 feet apart compared with $3\frac{1}{2}$ feet for other spacings, the yields on an acre basis necessarily present a more favorable result for 7-inch spacing than on a plot basis. Both 7-inch and 11-inch spacing of plants show markedly superior yields over matted rows under all conditions of moisture. The dry, hot season, prior to and during harvest, coupled with a dense stand of plants in the matted rows, probably accentuated the differences. The comparison of 7-inch spacing and 11-inch spacing shows these treatments about equal except under very low moisture supply when 11-inch spacing was superior.

Referring to Table II, it is evident that increased yields with plant spacing was due largely to increased numbers of larger berries, that is, increased size of berry, although *actual increase* in total number of berries does occur when the moisture supply is limited. Increase in water supply increased berry number only moderately in the $\frac{1}{2}$ -, $\frac{3}{4}$ - and 1-inch irrigation treatments.

The responses of plants to irrigation during harvest were particularly noteworthy in relation to spacing. Water was applied at harvest on plots (not previously irrigated) merely to save the badly dried and wilted plants, many leaves of which had died and which showed little fruit of value to harvest. It was surprising to get the results in Table III. Only small increases in yields resulted on matted rows but spaced plants gave large increases in marketable berries, especially with Dorsett and Fairfax. It was observed that these two varieties showed less actual wilting of plants than Blakemore or Premier with Catskill in an intermediate position.

Further comparisons of the behavior of the several varieties, averaging yields under all the conditions of moisture, are afforded in Table IV. With all varieties, the matted row was much lower in yield compared with the two spaced treatments. Blakemore produced the smallest quantity of larger berries (U. S. No. 1) especially under matted row conditions. Under spacing treatments, Dorsett and Fairfax were outstanding in production of marketable size, as well as total yields. In these yield comparisons, with each variety, on an acre basis, the 7-inch spacing was approximately equal in production to 11-inch spacing, although on a plot basis when spacing between the rows is not considered the 11-inch spacing was superior. Subtracting $\frac{1}{7}$ from the yield figures for 7-inch spacing will give the relative yields corresponding to the actual plot yields.

It is apparent that spacing of strawberry plants resulted in large yield increases and particularly made irrigation much more effective even when applied *at harvest* to plants that appeared incapable of production due to drouth injury. The effect of soil moisture on increasing the number of berries that developed is another feature of this work. Increasing soil moisture by irrigation under the hot, dry conditions increased yield by increased number of berries and increased size of berries. Differences in plant foliage also were evident in response to such irrigation.

Work is being continued on these same plots.

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Interrelation of Temperature and Photoperiodism in the Production of Fruit-Buds and Runners in the Strawberry

By GEO. M. DARROW, *U. S. Department of Agriculture, Beltsville, Md.*

ARTICLES previously published (1, 2, 3) have indicated the relation of photoperiodism to fruit-bud formation in the strawberry. Shortening of the daily-light exposure initiates the formation of fruit-buds. Several writers have suggested cool temperatures as a second cause of fruit-bud formation. Darrow and Waldo (4) from their work suggested that there was an interrelation of temperature and daily-light exposure, stating that "at temperatures above 60 degrees F short daily-light (10 hours or less) are necessary" and "at low temperatures fruit-buds may form under longer daily-light periods." They also "suggested that the rest period in the strawberry (and possibly in other plants of temperate regions) may be a result of nutritional conditions caused by relatively short daily-light periods and relatively low growing temperatures."

Kraemer (5) has given added evidence on this matter by obtaining, under long days, continuous vegetative growth of many kinds of tree seedlings that ordinarily have a low-temperature rest period.

This work was designed to study the inter-relation of temperature and photoperiodism in the production of runners and of fruit-buds in the strawberry. This paper is based on the records of nine varieties—Aberdeen, Blakemore, Burrill, Catskill, Dorsett, Fairfax, Howard 17, Klondike, and Bellmar—which represent widely different types as shown by their regional adaptation and previous tests of their photoperiodic response.

Beginning September 1, 1935, 27 plants of each of these varieties were placed in the greenhouse. Nine plants of each variety were exposed to the natural day, approximately $9\frac{1}{2}$ to $13\frac{1}{2}$ hours; nine to a 14-hour day; and nine to a 16-hour day (normal day plus artificial light after dusk as required). Beginning October 1, one-third of the plants at each day length (three plants from each variety) were exposed to as near 70 degrees F as possible, another third to 60 degrees F and the last to 55 degrees F. From November 1 to March 30 the average temperatures approximated those desired. The runners and flower clusters were picked off and recorded weekly. Because neither runners nor flower clusters can be picked off until possibly 2 to 4 weeks after they have actually been initiated, the records for any period indicate the condition of the plant 2 to 4 weeks previous.

A summary of the record on runner and flower-cluster production for the entire 5-month period is given by months in Table I. The records for the nine varieties have been added together.

The data show that regardless of the temperature, short days favor flower production and inhibit the production of runners. The long-day response is the reverse of this. The higher temperatures favor

TABLE I—EFFECT OF TEMPERATURE AND DAY LENGTH ON THE PRODUCTION OF RUNNERS AND FLOWER CLUSTERS IN STRAWBERRIES, NOVEMBER 1, 1935 TO MARCH 30, 1936

Treatment		Runners (R) and Flower Clusters (FC) Produced During Various Time Intervals					
Temperature (F)	Day Length	November R-FC	December R-FC	January R-FC	February R-FC	March R-FC	Total R-FC
70 degrees	16 hours	91-2	95-0	27-0	40-0	59-12	312-14
	14 hours	66-5	27-0	7-1	4-10	6-24	110-40
	Normal	0-24	0-41	0-74	0-61	0-81	0-281
60 degrees	16 hours	57-5	15-0	0-0	0-11	0-38	71-54
	14 hours	19-13	4-7	0-0	0-24	0-71	23-115
	Normal	0-26	0-16	0-14	0-53	0-70	0-179
55 degrees	16 hours	40-6	8-1	1-0	0-0	0-61	49-68
	14 hours	18-5	2-1	0-0	0-4	0-63	20-73
	Normal	0-18	0-7	0-2	0-14	0-92	0-133

runner production, but the most favorable temperature for flower production is dependent upon day length.

At 70 degrees, lengthening the day to 16 hours almost completely changed the plant response from flower to runner production. Except for two clusters produced early in November, only runners were produced until March, when the plants had become badly potbound. Then a total of 12 very small, weak flower clusters were produced by the 27 plants. This response corresponds to that in the field in most of northern United States where no fruit-buds are produced by most varieties in the long days of summer. Even with the 14-hour day at 70 degrees, runners were chiefly produced, and in regions having a 14-hour day and temperatures as high as 70 degrees, strawberries in the field respond in the same way. The gradual change toward flower production indicates that a 14-hour day at 70 degrees is nearly short enough for fruit-bud production.

Clearly, temperatures up to 70 degrees in winter are not effective in starting runner production under normal short days but do enable plants to produce flower clusters freely, while the lower temperatures limit both growth and the production of flower clusters. These results correspond with the response of plants in the field in Florida in winter.

At 60 degrees, runners were produced only in November and December in the 16-hour and 14-hour lots, and by March flower clusters were being produced freely by most varieties though more freely under the 14-hour than under the 16-hour day. These conditions correspond to the cool summers along the Pacific Coast where flower clusters are produced throughout the summer on mature strawberry plants. In central coastal California, for example, the yields per acre of the summer crop are the highest known in the world. Farther north along the Oregon and Washington coasts where the summer days are longer, fruit production is less.

With a still lower temperature, 55 degrees, runner production was less in the 16-hour and 14-hour lots and plant growth so small that few flower clusters were produced until there were many days with

relatively high temperatures in March. There are probably few regions where strawberry production is attempted with as long low-temperature periods as in this experiment. If summer temperatures were to go as low as 55 degrees for a considerable period at any point on the California coast, a slowing up of growth and flower-cluster production would be expected, while if temperatures go as high as 70 degrees, growth would be rapid but flower-production retarded.

Heretofore all varieties have been considered together. However, as shown in Table II, they have important varietal differences that correspond to field responses. Thus, at 70 degrees, with 16-hour and 14-hour days, six plants of Klondike produced 74 runners and no flower clusters but the six plants of Burrill produced 23 runners and 24 flower clusters. At 60 degrees under the 16-hour and 14-hour days, Klondike produced 19 runners and nine flower clusters, while Burrill produced two runners and 60 flower clusters. Apparently temperatures down to 60 degrees are much more effective in starting fruit-bud formation in Burrill than in Klondike. In full agreement on the California coast, Klondike produces very little in the summer. It seems to need days still shorter than 14 hours to form fruit-buds freely. On the other hand, evidence from these tests indicates that Burrill forms fruit-buds too freely and makes too little growth under 14-hour days. Dorsett produced 63 runners and four flower clusters in the 16-hour and 14-hour lots at 70 degrees, and 18 runners and 27 flower clusters at 60 degrees. Such a variety would seem intermediate between the two varieties in its field adaptation, and all field tests indicate that this is the case. A report from Dr. H. E. Thomas of the California Experiment Station reports the highest yield yet recorded from a field of this variety in the cool coastal climate near Watsonville. The other varieties are also intermediate between Klondike and Burrill in their response, the order being about as follows: Klondike, Bellmar, Blake-more, Aberdeen, Dorsett, Howard 17, Catskill, Fairfax, and Burrill.

TABLE II—EFFECT OF TEMPERATURE ON THE PRODUCTION OF RUNNERS AND FLOWER CLUSTERS BY THREE VARIETIES OF STRAWBERRIES—KLONDIKE, BURRILL, AND DORSETT—IN THE GREENHOUSE

Variety	Temperature	
	70 Degrees F	60 Degrees F
Klondike.....	74 R— 0 FC	19 R— 9 FC
Burrill.....	23 R—24 FC	2 R—60 FC
Dorsett.....	63 R— 4 FC	18 R—27 FC

In the northern fields in the fall it is desirable to have fruit-bud formation without immediate flower-cluster development. Apparently temperatures lower than 60 degrees with days shorter than 14-hours are most favorable in bringing this about, but under such conditions fruit-bud initiation proceeds at slower rates. With days as long as 16 hours at high temperatures, fruit-bud formation is largely prevented and no rest period is required for vigorous growth. In short days, little growth is made by any variety at 55 degrees F, and many tend to go into a resting condition. With short days and temperatures

of 60 and 70 degrees F, some varieties continue fruit-bud formation while others go into a resting condition.

The results to date support previously published work in indicating (a) that the rest period is the result of nutritive conditions caused by a short-day low growing-temperature complex; (b) that transformation of vegetative growing points into fruit-buds requires shorter daily-light periods at higher than at lower temperatures; and (c) that varieties exhibit characteristic temperature day-length responses which in large part determine their regional adaptation.

One possible experimental use of lengthening the daily-light period of strawberries is in obtaining a more accurate check on the time that fruit-bud differentiation starts and on the extent to which it has advanced at any given date. Potted plants of the different varieties were put under long-day conditions (16 and 14 hours) in the greenhouse September 1 and November 15, 1935 and September 1, 1936, and the flower clusters produced later were recorded.

TABLE III—FLOWER CLUSTERS PRODUCED BY STRAWBERRY PLANTS UNDER LONG DAYS IN THE GREENHOUSE

Variety	September 1, 1935		November 15, 1935		September 1, 1936	
	Number Plants	Number Clusters	Number Plants	Number Clusters	Number Plants	Number Clusters
Burrill . .	6	7	2	13	35	21
Dorsett	6	0	6	50	36	0
Fairfax	6	2	6	19	31	5
Howard 17	6	1	6	33	35	9
Klondike	6	2	—	—	27	0
Missionary	6	1	6	48	35	0

This indicates that the change from runner to fruit-bud production had already occurred by September 1 in 1935 in some plants of all except Dorsett, and in 1936 in Burrill, Fairfax, and Howard 17 but not in Dorsett, Klondike, or Missionary. Records for these 2 years indicate that exposure to 16-hour days at 70 degrees allows plants that are changing to develop the flower clusters already started or induced, which are too small even to be seen under the microscope, but it inhibits further initiation of fruit-buds. The number and size of the flower clusters appearing on the November 15 plants indicates that fruit-bud development at that time had proceeded to a greater extent.

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Seasonal Distribution of Yield and Size Variation for Some Everbearing Strawberry Varieties¹

By W. H. CHILDS, *West Virginia University, Morgantown, W. Va.*

A SMALL planting of everbearing strawberries was made at the Horticultural Farm, Morgantown, West Virginia, on April 28, 1936, to give some indication as to the comparative performance of the different varieties under the conditions found there. A 50-foot twin row of each of seven varieties—Champion, Empire All Red, Gem, Green Mountain, Lucky Strike, Mastodon, and Wayzata—was set with 12 inches between plants in the row and 12 inches between the members of the twin rows. A distance of 30 inches was left between varieties.

The soil is the Dekalb type, which is medium to poor in fertility, and had been in potatoes the previous year. A moderate application of manure, together with superphosphate and sulfate of potash at the rates of 300 pounds and 100 pounds per acre respectively, was turned under before setting the plants, and the plants were top-dressed with sodium nitrate at the rate of 150 pounds per acre on May 26. All blossoms and runners were removed at frequent intervals until July 1, and a mulch was applied at that time to keep the berries clean. Pickings were made at intervals of 2 days to a week, depending on the rate of ripening, until October 26, when a heavy frost ended the picking season.

While the planting was not large enough so that a comparison of total yields could be considered of much value, it is felt that the distribution of yield and the relative size of the berries give a true picture of what can be expected of the varieties under similar environmental conditions. A comparison of the varieties on the basis of these two points is given in the accompanying table and graphs. Since the pickings were made at irregular intervals, the figures given are weekly totals and averages for yield and size respectively, rather than figures for each picking. Empire All Red produced only about a third as much fruit as the next lowest variety, so it is considered distinctly unsuited to Morgantown conditions, and is not mentioned in the following discussion.

RESULTS AND DISCUSSION

The six varieties shown can be placed in three general groups on the basis of yield distribution. Gem reached a distinct peak in production early in the season and never approached that first peak during the rest of the production period. Practically half of the total yield was produced in the first 4 weeks. In contrast Champion and Green Mountain did not reach a distinct peak in production until the season was three-fourths past. Green Mountain produced over two-thirds of its crop in the last half of the season, while the distribution of yield was

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much more uniform in the case of Champion. The other three varieties had a distinct peak early in the season, followed by a period of relatively low production and then a second distinct peak in the last half of the picking period. In the case of Mastodon the peaks were of almost equal height, but with both Wayzata and Lucky Strike the later peak was considerably higher than the earlier one. This was especially pronounced for Lucky Strike.

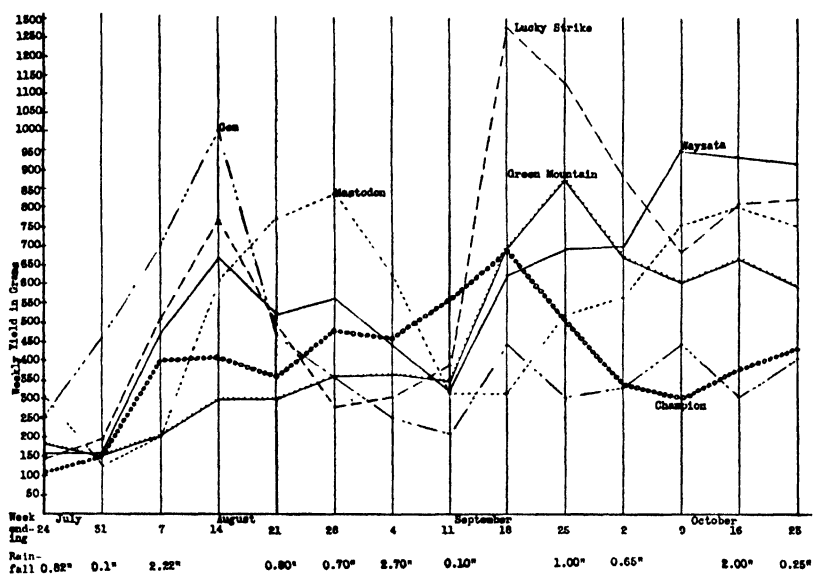


FIG. 1. Weekly yield variation for six everbearing strawberry varieties.

Rainfall seemed to have some effect on yield distribution, but only in that it tended to accentuate or lessen in degree the normal trend shown, for production to increase to a fairly distinct peak and then taper off to a period of relatively low yield. Probably heavy rainfall shortly preceding the period of heavy production would tend to accentuate the peak, while if it occurred when production was decreasing it would keep the yield from reaching the low level which would be reached in a dry period. This effect can be attributed to an increase in size of the individual berries as a result of the rain.

Only a slight correlation can be seen between weekly variation in size of the berries and weekly yield variation. The period in early September when the berries were smallest is also the period when yields were at low ebb, but weekly yield variation was much too great in most cases to attribute more than a small portion of it to size changes. The number of berries ripening was a much more important factor in influencing the yield than was the size of the individual berries. Rainfall seemed to increase the size of the individual berries for the following two or three pickings according to field observation, but this is so masked by other factors such as the proportion of primary, sec-

TABLE I.—WEEKLY YIELD AND SIZE VARIATION FOR SIX EVERBEARING STRAWBERRY VARIETIES

Week Ending	July		August				September				October				Total Yield	Average Number per 600 Grams
	24	31	7	14	21	28	4	11	18	25	2	9	16	23		
Rainfall (Inches)	0.82	0.10	2.22		0.80	0.70	2.70	0.10		1.00	0.65		2.00	0.25		
Champion																
Yield (grams).....	116	151	399	411	360	479	464	561	684	509	341	310	384	434	5603	320
Average number per 600 grams*.....	415	364	286	355	384	312	312	402	329	377	293	258	264	233		
Gem																
Yield (grams).....	261	468	705	997	472	357	249	213	443	305	336	442	306	412	5966	174
Average number per 600 grams.....	164	192	143	192	218	197	191	240	183	178	167	151	136	151		
Green Mountain																
Yield (grams).....	183	151	207	299	298	362	368	348	690	879	674	606	670	597	6332	180
Average number per 600 grams.	165	224	204	195	190	202	191	300	242	213	167	155	120	115		
Lucky Strike																
Yield (grams).....	142	188	518	775	488	280	308	384	1279	1133	889	684	814	823	8705	205
Average number per 600 grams.....	155	204	162	192	224	304	211	320	240	219	197	229	183	169		
Mastodon																
Yield (grams).....	316	131	207	626	774	842	629	317	316	520	570	762	807	759	7576	152
Average number per 600 grams.	148	225	142	123	134	157	176	264	257	161	149	135	113	124		
Wayzata																
Yield (grams).....	161	161	477	676	525	562	447	322	628	690	697	953	937	922	8158	175
Average number per 600 grams.....	175	184	149	188	179	207	235	361	245	195	150	139	134	140		

*600 grams equal approximately 1 quart.

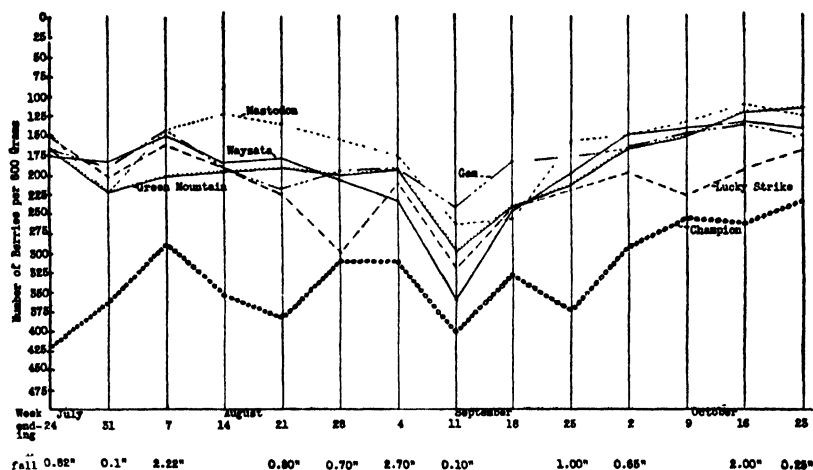


FIG. 2. Weekly size variation for six everbearing strawberry varieties.

ondary, and tertiary berries that the relationship can be seen but very slightly in the data presented.

The berries of Champion were consistently smaller than for any of the other varieties, and Mastodon produced the largest berries over most of the season, but the other varieties as a whole stayed fairly close together in size. Lucky Strike ran somewhat smaller than Wayzata, Gem, or Green Mountain, though one of them would occasionally be smaller for a picking or two.

It should be noted that the data presented are for only one season, and that the plants were not permitted to set any fruit until after July 1. If the same varieties were allowed to bear in the spring, the distribution in late summer and fall might be somewhat different. Also, results for several seasons would be necessary to show more clearly how much effect rainfall may have on yield and size variations.

The Effect of Shortening the Length of Day on Flower-Bud Differentiation and on the Chemical Composition of Strawberry Plants Grown During the Normal Growing Season¹

By ELMER W. GREVE, *University of Maryland, College Park, Md.*

UNDER normal growing conditions in the Northern part of the United States and Canada the strawberry plant differentiates flower-buds only during the fall months of the year. At that time of the year temperatures are lower and the length of day less than during the summer. This suggests that either temperature or photoperiod may be determining factors in the time when the strawberry differentiates flower-buds. This investigation was limited, however, to the effect of photoperiodism on flower-bud differentiation.

Sudds (4) in Pennsylvania found that by subjecting plants to an 8-hour day flower-bud initiation could be hastened in the Howard 17 strawberry. While the present investigations were in progress Darrow (2) published some results which showed that the standard varieties of strawberries may be classified as short-day plants.

MATERIALS AND METHODS

The Howard 17 variety was used in these experiments because of its commercial importance. An 11-hour photoperiod was selected since it represents the approximate length of day during September and October when flower-bud differentiation normally takes place.

Runner plants from mother plants set in the field in April, 1934, were rooted in 3-inch clay pots at frequent intervals during the summer, beginning June 22. When sufficiently rooted, the plants were severed from the mother plants and subjected to the photoperiod treatments. The plants were brought into the light at 7 a.m. and returned to the darkened chamber at 6 p.m. Watering was done as often as was necessary to keep the soil in the pots well supplied with moisture. Check plants were grown under identical conditions with the exception that they were grown under the length of day normal for the latitude of Washington, D. C., at the time of the year when the experiment was in progress.

After each group of plants had been under treatment for 15 days, a sample consisting of from 6 to 10 plants was taken for histological and chemical studies. Sampling was then continued at approximately weekly intervals throughout the course of these studies. In sampling, the tops were severed from the roots by a transverse cut just above the highest roots.

For the histological study, the buds were removed from the crown of the plant and fixed in an acetic-formalin-alcohol solution. The usual process was used to embed the specimens in paraffin. The sections were

¹This is a portion of a thesis submitted to the Faculty of the Graduate School of the University of Maryland in partial fulfillment of the requirements for the degree of Doctor of Philosophy. Granted, June, 1935.

cut 16 to 24 microns in thickness and stained in Delafield's haematoxylin.

Standard methods (1) were employed in the chemical analyses of the plants. One gram samples of the dried material were used for the nitrogen determinations and two gram samples for the carbohydrates. All reductions for the carbohydrate determinations were made according to the Munson and Walker method and the reduced copper determined by the Bertrand method.

Since microchemical examination showed no starch to be present in the samples, the residue left after the sugar extraction was used without further treatment for the acid hydrolyzable fraction.

EFFECT OF AN 11-HOUR DAY ON FLOWER-BUD DIFFERENTIATION

In a careful study of the sectioned buds it was found that the earliest flower-bud differentiation occurred in the sample of plants taken August 13. These had been rooted in pots on June 22 and subjected to an 11-hour day from July 9 until the time of sampling on August 13. The plants at this time were 52 days old (calculated from the time when roots first showed as small protuberances); and had received the short-day treatment for a period of 35 days. A week earlier, on August 6, a sample from the same group of plants had shown no differentiation of flower-buds. Another group of plants which had been rooted on June 29 and had been subjected to the short-day treatment from July 24 until the date of sampling showed first evidence of flower-bud differentiation on August 20. These plants were 52 days old and had been growing under the 11-hour day for 27 days. In still another group of plants, rooted July 12 and placed under the short-day treatment on August 1, flower-bud differentiation was first observed on August 27. At this time the plants were 46 days old and had been growing under the 11-hour day for a period of 27 days. By September 11 all the plants which had been growing under the 11-hour daily light period showed tertiary and in some cases quaternary flowers. On the primary flowers the sepals and petals had formed and the anthers were fairly well developed; and the secondary flowers were beginning to show the development of anthers.

In contrast with the 11-hour day plants, the plants growing under the normal length of day showed no definite flower-bud differentiation on September 11, at the time when this experiment was discontinued. In field-grown plants, differentiation of flower-buds was observed in samples taken on October 4. In all these studies, definite flower-bud differentiation was considered as having taken place when the growing point had become broad and flat and elongation had begun.

EFFECT OF AN 11-HOUR DAY ON THE CHEMICAL COMPOSITION OF THE PLANT

The data for dry weights, total nitrogen, total carbohydrates, and the total nitrogen/total carbohydrate ratio of the plants are shown in Table I. These data represent averages of two to four different lots of plants, each of which had been subjected to the same treatment for a comparable length of time. The figures for the number of days given in Table I

represent the number of days that the short-day plants were subjected to an 11-hour day.

The table shows that the dry weight of both the tops and roots was higher in the case of the plants grown under an 11-hour day. The total

TABLE I—THE EFFECT OF LENGTH OF DAY ON THE CHEMICAL COMPOSITION OF HOWARD 17 STRAWBERRY PLANTS

	Plant Part	Length of Day	Number of Days Under Treatment				
			15	20	29	34	40
Dry weight (grams)	Tops	11-hour	1.99	2.12	2.54	2.40	2.61
		Normal	1.92	1.59	2.51	2.18	2.18
	Roots	11-hour	0.89	0.87	1.08	1.26	1.43
		Normal	0.53	0.45	0.80	0.89	0.92
Total nitrogen (per cent dry weight)	Tops	11-hour	2.23	2.02	1.89	1.69	1.50
		Normal	2.46	2.52	2.28	2.26	2.34
	Roots	11-hour	1.41	1.38	1.29	1.01	1.05
		Normal	1.85	1.89	1.65	1.52	1.36
Total carbohydrates (per cent dry weight)	Tops	11-hour	18.87	20.49	21.86	23.28	25.57
		Normal	18.18	18.41	20.86	22.43	23.19
	Roots	11-hour	15.43	18.53	22.69	29.51	29.79
		Normal	16.73	18.19	18.63	20.63	22.32
Ratio of total carbohydrates to total nitrogen	Tops	11-hour	8.46	10.14	11.57	13.77	17.02
		Normal	7.39	7.30	9.14	9.92	9.91
	Roots	11-hour	10.94	13.43	17.72	29.21	28.37
		Normal	9.04	9.62	11.29	13.57	16.41

nitrogen content, on the other hand, was higher in the plants grown under a normal length of day. This was true for both the roots and tops. The total carbohydrate content of the tops was higher in the short day plants in every case. With but one exception (that of the plants under treatment for 15 days) the total carbohydrate content of the roots was also higher in the short-day plants. The carbohydrate/nitrogen ratio was calculated from the data for total carbohydrates and total nitrogen. In every instance the C/N ratio was higher in the short-day plants. The longer the plants were under treatment, the more striking this difference became. The effect of treatment on the C/N ratio is also shown graphically in Fig. 1. In addition to the differences already pointed out, the graph shows quite clearly that the ratio was much higher in the roots than in the tops in both the short- and normal-day plants.

When flower-buds were first observed in the short-day plants, which was 27 days after the beginning of the 11-hour day treatment, the C/N ratio was approximately 11 in the tops and 18 in the roots. At no time during the course of the experiment did the normal-day plants reach as high a C/N ratio. In this connection it should be remembered that the plants grown under a normal day had not differentiated flower-buds when this study was concluded.

In addition to total nitrogen and total carbohydrates, the following constituents were determined: soluble nitrogen, insoluble nitrogen,

reducing substances, sucrose, total sugars, and acid hydrolyzable polysaccharides (3). Lack of space prevents including these data here. However, the differences in these fractions between normal- and short-day plants were not as marked and were less consistent than those for total nitrogen and total carbohydrates.

The striking differences in the chemical composition of the strawberry plants grown under the normal length of day and the 11-hour day, together with the great difference in time of flower-bud differentiation, tend to emphasize a nutritional basis for the effect of length of day on differentiation of flower-buds. This viewpoint is often expressed, but not clearly demonstrated.

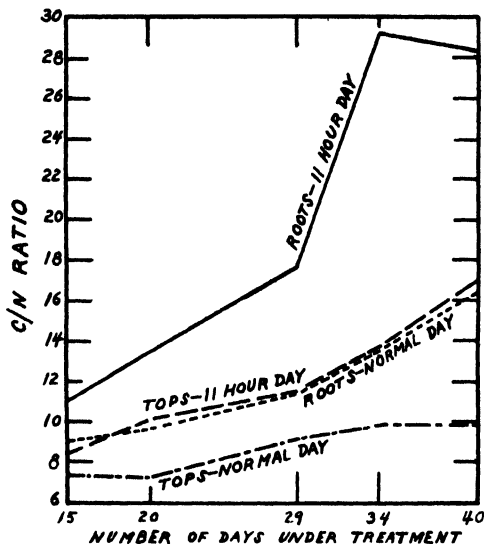


FIG. 1 Effect of length of day on the C/N ratio of Howard 17 strawberry plants.

CONCLUSION

From the results of this study flower-bud differentiation in the Howard 17 strawberry appears to be directly associated with the length of day under which the plants are grown. The length of day, in turn, influences the chemical composition of the plant, particularly the C/N ratio, and thus flower-bud formation seems to depend upon a nutritional condition within the plant.

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Preliminary Report on Raspberry Root Systems

By A. S. COLBY, *University of Illinois, Urbana, Ill.*

HOFFMAN and Schlubatis (1) working with red and black raspberries in Michigan have shown that root development and depth of penetration were closely correlated with the height of the water level. In connection with the studies being made of the methods of asexual propagation of purple raspberry seedlings at the Illinois Station (2), it was thought desirable to make more detailed observations on the root systems of certain raspberry species and hybrids under uniform environmental conditions.

This report is based on the root variation and distribution of one plant each of the following: Quillen black raspberry, Chief red raspberry, and two purple raspberries, crosses between Quillen and Starlight, and Quillen and June respectively. The individual bushes were chosen as representative of large numbers of similar plants. They were mulched in the row with about 2 inches of strawy manure renewed every 2 years as the material decomposed. Because of a deficiency of normal rainfall, the plants were irrigated as needed.

The bushes were located on the University of Illinois Horticultural Farm, Urbana, Illinois. The soil type is classified as brown silt loam,

with sub-soil of yellow clay beginning at depths varying from 2 to 3 feet.

The method of excavation was as follows: A trench was dug around the plant beyond the region of the roots and the soil carefully removed from the face of the trench until roots were encountered. Small hand tools were then employed to remove the soil in which the roots grew. Extreme care was used in order to preserve intact as many of the roots as possible. As each root was excavated, its position was located on a chart. The plant was then brought inside and suspended in front of a white background. There, the top and root were reconstructed in their original relative positions for photographing.

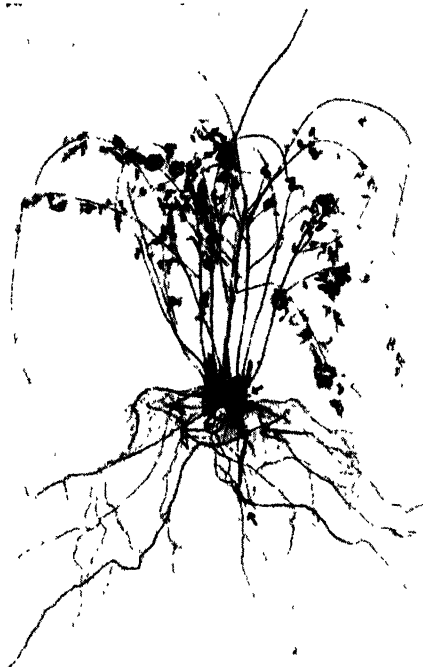


FIG. 1. Quillen Black Raspberry.

The general appearance of the Quillen black raspberry, including the portions both above and below ground, can be seen in Fig. 1. This plant was 6 years old. The double crown seems to be characteristic of the variety in about one-half of the 50 plants observed. The larger crown, indicated by the upper arrow, is the older. A short thick root connects the two. From the larger crown, a large woody tap root extended down about $1\frac{1}{2}$ feet; branching occurred at this point. One branch was broken while excavating, as indicated by the lower arrow. The remaining branch extended outward and downward to a depth of 3 feet. The majority of the main roots spread out

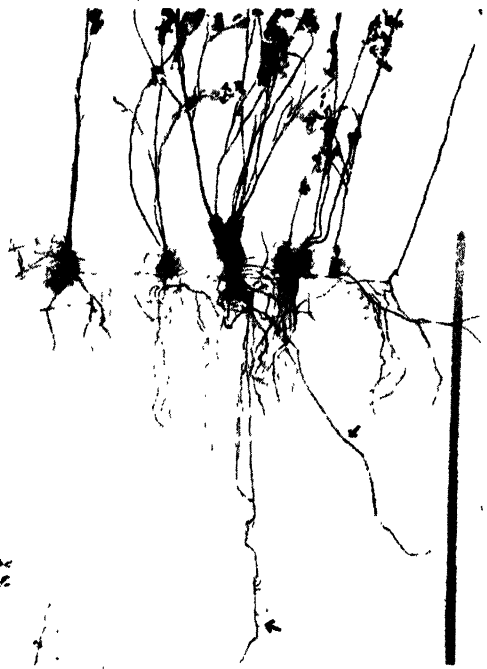


FIG. 2 Chief Red Raspberry.



FIG 3. Purple Raspberry. Quillen x Starlight.

horizontally for distances of somewhat over a foot, working their way thru the soil in a zig-zag manner, over and under other roots. They then took a downward and outward direction with a maximum depth of 3 feet. Most of the roots tend to branch when they begin to grow downward. Many of these rootlets, especially those at the extremities, were so small and brittle that they could not be retained for reconstruction of the root sys-

tem. Root spread exceeds branch spread. No evidence of sucker formation could be found on the roots.

In Fig. 2 is shown a 6 year old plant of the Chief red raspberry. In general, the red raspberry root system is less widely spread but potentially deeper than that of the black. The main roots are more slender and brittle. Those from the mother plant extend to a maximum depth of 5 feet 9 inches. Tap roots, either branched or unbranched, are found on some of the individual plants. Small rootlets occur in abundance, both as laterals and terminals. Ten young sucker plants naturally differing in size and age, are in evidence. Five others, some of which have just begun to grow, are not distinct in the photograph. Originating from adventitious buds, most of these suckers are found on the more or less horizontal roots within 9 inches from the surface. These roots extend out from the main crown in all directions. There was no uniformity in spacing of the suckers. In some cases the roots of the suckers have a tendency to grow out in whorls, one whorl arising at the base of the sucker close to the point of attachment to the older root, and another an inch or more above it.

During the excavation process, several suckers were found growing at depths from 2 feet 9 inches to 5 feet 3 inches, as indicated by the arrows. These suckers were two or more inches long, creamy-white in color, and growing vigorously, when the plants were dug on November 6. They shriveled and turned dark, however, before the photograph could be taken. Environmental conditions, including aeration and moisture were evidently favorable for adventitious bud development at that time at these soil levels.

A purple raspberry hybrid, Quillen by Starlight, 8 years old, is shown in Fig. 3. Characteristics of both parent species are evident. There is a tendency toward the willowy branching habit of the red raspberry, but more strongly toward the formation of large strong main roots with many small fibrous laterals and terminals that are characteristic of the black. Hybrid vigor is indicated by a more extensive root system than that of either parent. The secondary roots spread through the soil in all directions, filling it to a depth of more than 3 feet. A maximum depth of $5\frac{1}{2}$ feet was reached with a spread of $6\frac{1}{2}$ feet. Plant with this type of root system are well fitted to withstand unfavorable weather conditions.

It is also interesting to note the occurrence of suckers that ordinarily are not produced by purple raspberries. Eight sucker plants are shown, the three smallest being indicated by arrows. Four smaller newly formed plants cannot be seen in the photograph. Some of these originated at lower soil levels than did the majority in the red raspberry. Favorable environmental conditions at certain periods during the growing season evidently resulted in the development of adventitious buds because several small newly formed suckers were found at different soil levels down to about 2 feet, as indicated by the arrows.

In Figs. 4 and 5 are shown two raspberry bushes propagated by tip layers the same year from the same parent plant, a cross between Quillen and June. These plants were 3 years old. They were root pruned by pushing a tiling spade straight down to a depth of 14 inches, plant

No. 4 being pruned at a distance of 6 inches from the crown, and plant No. 5 at a distance of one foot. This pruning was done in July 1936 and the plants were dug the following November. The plants grew within a few feet of each other and the other cultural operations were identical.

A comparison of the two plants is interesting in that the more closely pruned plant is much less vigorous both in root and top growth. In the larger of the two plants, root pruning was much less severe since the spade did not cut so many of the roots in the center immediately beneath the



FIG. 4. Purple Raspberry Quillen x June. Summer Root pruned, 6 inches from crown.

crown. Another fact should be noted, one which has an important bearing upon root injury from deep cultivation and the spread of certain soil borne diseases. Galls developed in every case where the roots were cut. These were identified as crown gall by Riker of Wisconsin. In some cases (indicated by arrows) the two cut ends of the roots grew together. Crown gall formation also occurred at the points of union. No evidence of the dis-



FIG. 5. Purple Raspberry. Quillen x June. Summer Root pruned, 12 inches from crown.

ease was found on the roots of these individual plants unless they had been injured.

In these studies of raspberry plants, the distribution, concentration, and differentiation of the roots were found to be influenced by the genetic constitution and age of the plant, and by the moisture, nutrient supply and aeration of the soil.

Summer pruning of purple raspberry roots, of varying degrees of severity exerted a more or less marked influence on later root and top growth, depending upon the degree of severity used. When roots were cut, even though the cut ends healed, the injured area became infected with crown gall.

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Some Evidence Relating to the Downward Movement of Photosynthate in Fruiting Canes of the Red Raspberry¹

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THE relationship between the fruiting and the new canes relative to the use of, and competition for, the products of photosynthesis is one of the many interesting problems of plant behavior in the red raspberry. Sablon (4) showed that there is an increase in the concentration of carbohydrates in the fruiting cane during the development of foliage, flowers, and fruit, followed by a marked decline until late in the season when a considerable amount of residual material accumulates and remains in the canes. It has been shown by a number of workers that the downward movement of carbohydrate material in stems is arrested above a girdle. Bennett (1) and Clements (3) found that girdling in the red raspberry generally was followed by the development of callus at the upper edge of the girdled area. This indicates that a downward movement of food substances in the fruiting cane is arrested by girdling. Brierley (2) found that from spring until the height of the picking season, there was a general decline in the concentration of sugar which was followed by an increase that appeared to be associated with phloem breakdown. Breakdown of the phloem at the base of the canes doubtless acts in the same manner as a girdle to prevent the downward movement of sugar. Although these studies present information relating to the movement of food substances in the cane further data was desired to determine if there was a general downward movement of photosynthate in fruiting canes and, if so, when such movement occurred.

To obtain information relative to the growth behavior subsequent to girdling, canes of the Latham variety were girdled in the early spring of 1933. Strong canes were selected at random and one lot was girdled at the base only; a second lot was girdled in three places, at the base, in the middle, and about 18 inches from the tip; and a third group of canes was selected in which well developed buds were isolated by girdles made just above and below the node. Girdled areas were covered with grafting wax to prevent drying. All of the girdled canes grew and fruited normally and could not be distinguished from untreated canes. In practically all cases, however, there was callus formation and increase in stem diameter near the upper margins of the girdled areas. This was observed at the time the first terminal blossoms opened. Although callus growth and increase in stem diameter were noted in the canes girdled in three places and also in the case of isolated laterals, the largest overgrowth was found on canes with a large foliage area, that had been girdled only at the base.

In 1935 the study was continued by girdling 25 canes each of the

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Latham and Chief varieties at the time the buds were swelling in early spring. These canes were girdled at the base only and the wounds covered with grafting wax. None of the canes in the field were vigorous early in the spring due to injury by drouth and red spider in 1934. As the season progressed, however, the girdled canes could not be distinguished from untreated canes. Growth and fruiting behavior were in no way different from that of canes not girdled. At the height of the fruiting season representative samples of girdled and untreated canes of both varieties were collected and examined for the presence of starch and sugar.

Thin cross-sections of cane were examined microchemically. Iodine potassium iodide was used in testing for starch which was never positively identified in any of the sections investigated. The Flückinger reaction was used in testing for sugar. In making this test, sections of cane were placed on a microscope slide in a solution of copper tartrate dissolved in 15 per cent sodium hydroxide and covered with a cover glass. As cuprous oxide crystals never appeared without one to two minutes heating at 40 degrees C it was assumed that fructose was either absent or present in very slight amounts in the raspberry cane material examined. Upon heating, copper oxide crystals appeared in proportion to the amount of reducing sugar present. This indicates that the sugar present is glucose or reducing sugars resulting from the hydrolysis of sucrose or other carbohydrate material.

In canes of the Latham variety, a slight development of callus was accompanied by somewhat greater concentration of sugar than in the canes not girdled. In canes of the Chief variety, with no apparent callus development, there was no detectable difference in the concentration of sugar between the girdled and untreated canes. At the end of the harvest season tests showed that in weak canes without visible callus formation there was no greater concentration of sugar above the girdles than in untreated canes. In girdled canes showing callus formation and a slight overgrowth, however, a greater concentration of sugar was found than in untreated canes.

In these observations it was noted that callus development and increased concentration of sugar apparently were more closely associated with an extensive foliage area than with cane diameter.

Similar studies were carried on during the growing season of 1936. Although the canes produced during 1935 were vigorous, weather conditions during the season of 1936 were not favorable to growth because of protracted drouth and high temperatures. More than a hundred canes each of the Latham and Chief varieties were girdled at the base in early spring.

The first indications of callus growth were observed in the Chief variety on May 25, when the blossom buds were first distinguishable. On June 3, when the first terminal blossoms were open in the Chief variety, callus development could be seen. It was more advanced in the Chief than in the Latham which is a later variety. In both varieties the most noticeable development of callus was found immediately below vigorous fruiting laterals. At this time, and at all later dates, examination of comparable girdled and untreated canes showed no evidence

of starch. After hydrolysis, sugar was noted in considerable quantity. With one exception there was apparently no more in the region immediately above the girdles than in the same region in comparable untreated canes. In the Chief variety one girdled cane appeared have a slightly greater concentration of sugar in the basal region than was found in comparable untreated canes.

On June 10, when the first terminal berries had set in the Chief variety and the first blossoms were opening towards the tips of the Latham canes, the callus growth could be seen breaking through the covering of wax. Sugar was found in considerable quantities but no difference could be observed between the girdled and untreated canes in either the basal or central regions.

On June 17, when the terminal berries of the Chief variety had attained nearly mature size and those of the Latham were enlarging at a rapid rate, callus growth was developing rapidly above the girdled areas in the majority of canes. At this time the concentration of sugar in both the basal and central regions of the canes was greater above the girdles than in untreated canes.

On June 24, terminal berries of the Chief variety were beginning to color and those of the Latham were growing rapidly. Callus growths in both varieties were increasing rapidly in size. As in the previous examination, the concentration of sugar after hydrolysis was found to be greater above the girdles in vigorous canes than in comparable untreated canes. In both varieties, however, an examination of the less vigorous canes that had less than the normal development of foliage showed no greater concentration of sugar than in comparable canes not girdled. At the time of the next examination on July 1, the first picking had been made of the Chief variety. Terminal berries of the Latham variety were almost fully developed but had not begun to ripen. Callus growth apparently had ceased in all samples examined at this time, a much greater concentration of sugar was noted above the girdles than in comparable canes not girdled.

On July 8, at the time of the fourth picking for the Chief variety and the first for the Latham, tests showed sugar present in considerable quantity. There was more sugar above the girdled areas than in untreated canes.

Protracted drouth and high temperatures scalded the berries and a premature decline of the fruiting canes was occurring at the time of the last examination on July 15. In all cases there was noticeably more sugar above the girdles than in the canes not girdled. There also was evidence in some cases of an increased concentration in the central region of the girdled canes as compared to untreated canes.

It has been mentioned previously that callus over-growth developed at the upper margins of the girdled areas at different heights on the cane, and below isolated laterals. This indicates that there was a downward movement of food in the individual fruiting lateral as well as at all heights of the cane itself. The data obtained in these studies indicate that strong canes with large leaf areas may produce a surplus of sugar after the needs for growth have been met. This surplus appears to accumulate in the region above basal girdles beginning about the time

the blossom buds are appearing and when elongation of the fruiting laterals has practically ceased. Increase in the concentration of sugar in girdled canes was noted from that time until the decline of the fruiting canes. Weakened canes, or those with sparse foliage, usually did not show an accumulation of sugar above the girdles. Apparently the vigor of the canes in the fruiting season, as expressed by the extent of foliage development, had more effect upon the production and downward movement of surplus sugar than vigor of the canes in the previous season as shown by cane diameter.

It was noted that callus over-growth and accumulation of sugar in girdled canes occurred at the time of most rapid growth in the new canes. These and other studies of the behavior of the red raspberry relative to possible competition between fruiting canes and new growth do not make it appear likely that any competition that may exist is harmful to canes of either age. It is more likely that the relationship is a cooperative one such as is found in other woody plants. At the time the fruiting laterals are growing rapidly it is very likely that food stored in the canes and roots may be transported upward and used to promote growth. When the fruiting laterals have about finished their growth and a large foliage area is forming photosynthate in excess of the needs of the fruiting canes, the surplus may be transported downward for use or storage in other parts of the plant until translocation of sugar is prevented by the normal senescent breakdown of the phloem.

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The Relation of Catalase Activity to Growth in the Latham Raspberry¹

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STUDIES of the seasonal rate of elongation of black raspberry canes by Darrow (3) and of red raspberry canes by Brierley (1, 2), have shown the march of growth throughout the season, and have indicated the effects of light, temperature, transpiration and moisture supply upon cane growth. It is generally recognized that catalase activity is in some way associated with growth. Pope (5) has shown that catalase activity in barley is roughly proportional to the reciprocal of the growth rate, being in general lowest during the stages of most active growth. The present studies were undertaken during the growing seasons of 1933 and 1934 to determine the relation between catalase activity and growth rate in the red raspberry.

In 1933 the material used in these studies was obtained from the plots at University Farm. Fruiting canes or laterals and the upper portions of the new canes were cut in the field in the morning, placed in jars of water and taken immediately to the laboratory where the catalase activity was determined by means of the apparatus designed by Landon (4). In 1934 the material for study was cut in the field in the late afternoon at the University of Minnesota Fruit Breeding Farm, placed in jars of water and taken to University Farm where it was kept over night in a cool cellar. The catalase determinations were made the following morning.

The procedure described by Landon (4) was followed in making the catalase determinations. As the catalase activity of some of the material tested was high, tissue preparations containing one part tissue to 100 parts of water were used. The hydrogen peroxide used was 14-volume in strength, *i.e.*, 1 cc would evolve 14 cc of oxygen when placed in contact with manganese dioxide.

To obtain reasonable uniformity in the tissue samples taken at the different stages of growth, a standardized procedure was followed. In the case of the new canes, samples of the developing tips were taken in such a way that all unfolding leaves were excluded. For the leaf samples, lateral leaflets were taken from the two uppermost fully expanded leaves. Samples of the leaves of fruiting canes were taken in a similar manner from the fruiting laterals. For the samples of the tips of the fruiting laterals the procedure necessarily changed with seasonal development. The early samples included the developing tips with all unfolding leaves excluded. Later samples in the respective growth stages included young flower buds and attached parts; open terminal flowers and a few large buds; developing berries with receptacle, calyx and pedicel attached; ripe terminal berries with similar attached parts; and lastly, in 1933, the more or less dried receptacle and attached

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parts. In all cases the material was taken from several individual canes in order to obtain representative samples.

Determinations of the catalase activity were made at fairly definite growth stages evidenced in either the new or fruiting canes. The first

TABLE I—CATALASE ACTIVITY IN NEW AND FRUITING CANES OF THE LATHAM RASPBERRY IN 1933. DATA EXPRESSED IN CC OF O₂ EVOLVED IN 10 MINUTES BY 2 CC OF TISSUE PREPARATION

Date	New Canes			Fruiting Canes		
	Stage of Growth	Leaves	Tips	Stage of Growth	Leaves	Tips
May 15	Canes 3 to 4 inches long	15.0	4.0	Laterals 2 inches long	20.1	5.0
May 29	Canes 8 inches long	15.7	3.0	First blossom buds visible	12.1	
June 9	Canes 15 inches growing rapidly	6.2	1.8	First blossoms open	8.8	1.7
June 20	Canes 24 inches growing rapidly	7.3	1.8	Terminal berries enlarging	11.0	1.2
July 5	Canes 36 inches growth slowed by drouth	6.0	1.5	Terminal berries ripening	6.9	—
July 31	Canes 48 inches growth slowed by drouth	6.1	1.6	End of harvest period	6.8	0.9
August 31	Canes 54 inches to 60 inches growth checked by drouth	7.9	1.8	—	—	—
September 28	Canes 54 to 60 inches growth completed	10.7	2.2	—	—	—

determinations in each season were made at the beginning of growth when the fruiting laterals were 1 to 2 inches long, with the first few leaves fully expanded. Later determinations were made at the following stages of growth: first blossom buds visible; first blossoms open; terminal berries enlarging; terminal berries ripening; end of harvest period; growth of new canes nearly completed; and finally, when the new canes were judged to be nearly matured, but before leaf fall.

Rainfall in both 1933 and 1934 was below normal, particularly in 1934. In 1933, the early season was favorable but drouth during July and August probably shortened the growing season somewhat. However, growth and catalase activity for this season may be considered fairly typical of the red raspberry under Minnesota conditions. The growing season of 1934 followed an exceptionally dry winter which caused severe desiccation injury to the over-wintering canes and also may have affected the root systems. Growth of fruiting laterals was below normal. The new canes started growth late and development was

sub-normal until early June when a soaking rain was followed by more vigorous growth. Drouth conditions again prevailed through July and August, resulting in a slowing of growth and early maturity. The growth during 1934 was markedly lacking in vigor. The differences in catalase activity for the two seasons probably can be accounted for by these differences in the growth response.

TABLE II—CATALASE ACTIVITY IN NEW AND FRUITING CANES OF THE LATHAM RASPBERRY IN 1934. DATA EXPRESSED IN CC OF O₂ EVOLVED IN 10 MINUTES BY 2 CC OF TISSUE PREPARATION

Date	New Canes			Fruiting Canes		
	Stage of Growth	Leaves	Tips	Stage of Growth	Leaves	Tips
May 5	No new growth—severe drouth	—	—	Laterals 1 to 2 inches long	23.6	8.1
May 31	New growth short poorly developed	24.5	5.3	First blossom buds visible	24.1	4.4
June 8	Growth somewhat more vigorous	22.0	3.3	First blossoms open	19.4	2.7
June 19	Growth somewhat more vigorous	25.0	5.3	Terminal berries enlarging	25.0	—
July 7	Canes growing rapidly	20.8	4.1	Terminal berries ripening	24.1	—
July 28	Slow growth—drouth	17.6	4.4	End of harvest period	22.3	—
September 5	Growth nearly completed	17.7	3.8	— — —	—	—

The determinations of catalase activity in the new and fruiting canes of the Latham variety of the red raspberry at the several growth stages during the season of 1933 are shown in Table I. These data show a decline in the catalase activity in the leaves and tips of the new canes during the period of most rapid growth, followed by an increase in activity as the canes approached maturity. In the fruiting canes there was no increase toward the end of the growing season. This behavior probably was due to the senescent condition of these canes after the harvest season. In general, the catalase activity in both the new and fruiting canes followed very closely the behavior in barley as noted by Pope (5). The catalase activity during this season was obviously lowest during the period of most active growth, and the rate was approximately the reciprocal of the growth rate previously reported by Brierley (1).

These studies of catalase activity were repeated during the season of 1934 and the results are shown in Table II. The data for new canes in this season do not show the expected reciprocal of the growth rate as clearly as in the previous season, probably as a result of unfavorable weather conditions. A decline in the response in both the leaves and tips toward the end of the season is evident but no recovery was noted such as occurred in 1933.

In the leaves of the fruiting canes catalase activity was erratic, but continued throughout the season at a higher rate than was found in 1933. No decline in activity was evident in the leaves on May 31 when the first blossom buds were visible. This is the stage at which the rate of stem elongation should be at its maximum. Some decline in activity accompanied the opening of the first blossoms of June 8 when the rate of stem elongation was declining. It is probable that the prolonged drouth and high temperatures produced an abnormally early senescent condition in the foliage of the fruiting laterals. It is probable also that a similar early senescent condition affected catalase activity in the tips of the fruiting laterals. Observations of growth in the field showed clearly that both the new and fruiting canes were considerably below normal vigor.

The results in 1933 indicate that normal catalase activity accompanies normal growth in the Latham red raspberry. In 1934, however, when weather conditions were markedly unfavorable, abnormal catalase activity accompanied subnormal growth.

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Further Studies of the Absorption of Water by Red Raspberry Foliage, and Some Evidence Relative to the Movement of Water within the Plant¹

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EARLIER studies (1) of the ability of foliage to absorb water have shown, in the course of laboratory experiments, that the foliage of the red raspberry absorbs water readily under certain conditions. A somewhat similar study was carried on in 1935 with the Latham variety under field conditions. Representative hills were selected and water-proof paper placed on the ground around them to prevent wetting of the soil. The plants were then sprayed at frequent intervals for a period of 2 hours with tap water at air temperature. As soon as the foliage dried, samples were taken of the leaves and stems to determine their moisture content. Comparable samples were taken from check plants at the same time. No significant differences were found between the moisture content of the foliage and stems of the sprayed plants and that of the checks. This indicates that spraying did not increase the amount of water within the plants. These negative results probably were due to the fact that the plants were growing in a retentive soil in which there was an ample supply of water for their needs.

The study was continued in 1936 with Latham plants grown in metal tubs. The tubbed plants did not grow as vigorously as plants in the field but the foliage was fairly abundant and a good crop of berries was produced on the fruiting canes. When the berries were nearly mature, water was withheld until the tips of the new canes drooped and the foliage wilted. During wilting, the moisture content of the soil in the tubs was reduced from 21 to 24 per cent to 12 to 16 per cent.

Two of the wilted plants were placed in the shade and the entire tops sprayed at frequent intervals with tap water. The tubs were placed on their sides so that no water could fall on the soil. Recovery was slow, but turgidity was regained in about 3 hours. It was necessary to keep the foliage continually wet to prevent the recurrence of wilting as the study was carried on at temperatures ranging from 99 to 104 degrees F with a very low relative humidity. The plants were held over night without watering and were wilted again the following morning. Turgidity was regained at that time by frequent spraying during a 2 hour period.

The new and fruiting canes on two similar wilted plants were separated by means of waterproof paper and water was sprayed on the new canes only. Although it was somewhat difficult to keep the leaf surfaces wet on account of a drying wind with a temperature of 90 degrees F, turgidity was restored in 2 hours in both the new and fruiting canes. Apparently the water absorbed by the foliage of the new

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canes was conducted downward to the crown and then upward into the fruiting canes.

In another pair of wilted plants in which only the fruiting canes were sprayed, turgidity was restored in the sprayed canes in 3 hours, but the new canes did not recover completely in that time. Apparently not enough water was absorbed by the fruiting canes to meet the needs of the new canes.

Two wilted plants were placed on their sides and the entire tops submerged in a pan of tap water. In this case turgidity was restored in 1 hour. The tops were then removed from the water and within 1 hour they were wilting again. When again submerged, turgidity was restored in 1½ hours. By varying the treatment relative to the parts submerged it was found that turgidity could be maintained in one or two new canes if at least one new cane was submerged together with all of the fruiting canes on the plant. When only the fruiting canes were submerged they appeared to be unable to restore turgidity completely in the new canes. The foliage of the older canes was beginning to lose its dark green color and appeared to be in the early stages of decline. When only the new canes were submerged the fruiting canes were maintained in a turgid condition. Apparently the water absorbed by the foliage was conducted readily from one part to another although the fruiting canes alone did not absorb or conduct enough water to meet the needs of the new canes.

Water was supplied to another pair of wilted plants by a third method. The tips of two strong fruiting canes and two of the strongest new canes were cut back just far enough for 5 mm rubber tubing to fit over them without leakage. The tubes were connected to a reservoir 4 feet above the tips of the canes and water was conducted to the canes immediately after the tips were cut off. In each plant there were four or five shorter new canes to which no water was supplied. Both the new and fruiting canes to which water was supplied regained turgidity in 1½ hours. In 3 hours the shorter new canes also regained turgidity, indicating that water had moved downward into the crown and then upward into these canes. Apparently the water taken in through the tips of four canes was sufficient to maintain turgidity in all the canes even under conditions of high temperature and low relative humidity.

The ability of the red raspberry cane to conduct water both upward and downward was demonstrated in the field by following the method described by Zimmerman and Connard (2). The work was done at the time the blossom buds were enlarging. Several strong canes of the Latham variety were selected and a cut made near the base of each cane 2 to 3 inches below a strong fruiting lateral. Each cane was then split upward from the cut through the middle to a point 2 to 3 inches above the lateral. A strip of heavy waterproof paper was inserted to separate the two portions of the cane and the wounds were tied securely and waxed to prevent drying. Under conditions of severe drouth and high temperature the laterals on the split portions of the canes continued to develop flowers and fruit with no indication of wilting. Apparently water was conducted downward from above the

wounds in sufficient quantity to maintain these laterals. No evidence of wilting or drying was noted until the entire field was affected by heat and drouth. When all fruiting canes were drying and the tips of many new canes were wilting, these fruiting laterals also began to fail, but, as long as an adequate supply was available in the soil, water apparently was conducted readily both upward and downward to these laterals.

It is generally recognized that the water conducting capacity of a woody stem is in excess of the actual needs of the top. In order to determine whether or not the red raspberry cane can function with a reduced conducting area, a study was begun in the early spring of 1936. Twelve representative hills of both the Latham and Chief varieties were selected. In each hill one-fourth of the stem was removed at the base of one vigorous cane, one-third removed from a second cane, and one-half removed from a third cane. All the wounds were made by means of radial cuts extending into the pith and a piece of stem about 2 inches long was removed. The wounds were covered with grafting wax to prevent drying.

From the beginning of the growing season until the fruit was ripening no difference could be detected between any of the treated and untreated canes in the same hill or elsewhere in the field. Because of severe drouth and high temperatures, all the fruiting canes in the field began to dry up about the middle of July. At that time the canes with one-fourth or one-third of the stem removed were in as good condition as the average of the field. Sixty-six and one-third per cent of the canes from which one-half of the stem had been removed were in as good condition as the average of the field, but 33 $\frac{1}{3}$ per cent were drying more rapidly. The rate of water movement may have been increased through the restricted portions of the canes to offset the reduction in conducting area, but the reduction in area appeared to have no detrimental effect in some of the canes from which one-half of the stem had been removed.

It is apparent that the number, size, and to some extent, the length of the tracheae may affect the movement of water in the raspberry cane. Both the number and diameter of the tracheae vary in canes of different diameter, the number also decreases materially towards the tips of the canes where the xylem area is greatly reduced. There appears, however, to be somewhat the same range in tracheal diameter towards the tips although the number of tracheae is less. A study of the length of tracheae by means of mercury under 300 mm pressure showed a significant decrease in length from the base towards the tips. In canes of the Chief variety the length of the vessels in the basal, central, and sub-apical regions were found to be 19.96, 18.28, and 13.29 cm, respectively. In canes of the Latham variety the lengths of vessels in similar regions were found to be 20.78, 16.55, and 11.17 cm, respectively. As the studies of the movement of water in the cane indicate that such movement takes place readily in either direction, it does not appear likely that the variations in length of the tracheae affect the ease of water movement.

From the evidence obtained in these studies it would seem that when

there is a deficiency in soil moisture the foliage of the red raspberry can absorb water and that the water so absorbed moves readily within the plant. Water appears to move readily either upward or downward within the canes. The conducting capacity of the individual cane is considerably in excess of the minimum requirements of the cane, and the ease of water movement appears to be independent of the observed variations in the number, diameter and length of the tracheae.

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Further Studies of Transpiration Rates of Fruiting Canes and Current Season Shoots of the Black Raspberry¹

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IN a preliminary paper presented before this society four years ago, the writer (2) reported that the mean water intake per square centimeter of current season shoot foliage of the black raspberry to be 36.6 per cent greater than that for foliage of fruiting canes when the excised shoots and canes were connected in separate series to potometers set up in the greenhouse. Parallelism of transpiration rates for the two kinds of foliage also seemed to be a significant feature of the study made in 1932.

POTOMETER STUDIES, 1933

Similar studies were made on a somewhat larger scale and under slightly different conditions the following summer. In 1933, each excised cane or shoot was connected with an individual burette rather than series assembly. The plant parts were placed outdoors to more closely approximate field conditions and were connected to burettes in the laboratory. Thirty-six determinations were made in triplicate between June 20 and July 22, the duration of tests being 60 or 90 minutes.

The mean water intake per 1000 square centimeters of current season shoot foliage per hour for the period included in the study was 22.89 ± 0.44 cc while that for foliage of fruiting canes was 19.24 ± 0.48 cc. The leaves of the shoots transpired at a significantly higher rate than did cane foliage for the period as a whole, but during the days of July 3 to 6, inclusive, when the first berries were ripening, the reverse was true. Furthermore, the seasonal trends for transpiration rates were not parallel for a greater portion of the period under study. There was, however, a strong indication that leaves of fruiting canes decline in transpiration rates near the end of the fruiting period while foliage of shoots maintains the mean level.

Differential cultural treatments, to provide unpruned, irrigated, and nitrogen fertilized plants, were practiced in the field that supplied the plant materials for these studies. The cane foliage of unpruned plants gave consistently and significantly higher water intake values per unit of leaf area than cane foliage from plants that had been subjected to commercial pruning practices plus either fertilization or supplementary irrigation. Furthermore, canes bearing light green or yellowish green foliage gave significantly higher rates of transpiration than dark green foliage canes. However, the shoot foliage of unpruned plants transpired at a slower rate than such leaves from fertilized or irrigated plants. Thus, cane foliage of unpruned plants gave transpiration rates more than 30 per cent greater than shoot foliage from these same plants.

FIELD TRANSPIRATION

Between June 17 and July 24, 1933, a slight modification of the method described by Heinicke (1) for determining transpiration

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rates in the field was employed. The weighing bottles containing calcium chloride were attached to leaves with full exposure to possible sunlight for 4 or 5 hours. Eight cane and eight shoot leaf determinations were made simultaneously on each of 14 days. The mean water absorption per 1000 square centimeters leaf area per hour for the lower surfaces of current season shoot foliage was 14.14 ± 0.55 cc while that for fruiting cane foliage was 12.08 ± 0.53 . Though the mean difference is hardly significant, the cane foliage gave a higher average transpiration rate for only 1 of the 14 days. Incidentally, one replicated determination showed the lower surfaces of cane and shoot leaves gave off moisture more than 15 times as rapidly as the upper surfaces.

TRANSPIRATION STUDIES WITH POTTED PLANTS, 1935 AND 1936

In April, 1933, 25 carefully selected nursery tips of the Cumberland variety were planted in as many 8-gallon paint cans, which could be thoroughly sealed. Each can contained the equivalent of 75 pounds oven dry compost, which had been thoroughly mixed to provide uniform soil conditions. Into each can of soil was inserted vertically a special porous concrete watering tube. The plants were growing in these cans until June 10, 1935, when 12 plants were initiated as a high moisture series, and 12 as a low moisture series. The high moisture soils varied from 24 to 17 per cent moisture in 1935, dry weight basis, and the low moisture soils from 17 to 11 per cent (the wilting coefficient was between 8 and 9 per cent at this time). Four of the plants maintained at each soil moisture level were entire, *i.e.*, contained both canes and shoots; four at each level consisted only of current season shoots, and four of each series consisted only of fruiting canes (new shoots were pinched out as rapidly as they attempted to develop). All cans were thoroughly sealed with paraffined cloths. The weights were checked daily from June 12 to July 29, 1933, and gross weights brought up to the maximum level for the soil moisture series provided these weights were 3 or more pounds below such levels.

All discolored and injured leaves were removed from the plants and measured at weekly intervals. In the case of the growing shoots, dated tags were tied at the extremities of estimated full leaf development once a week. At the end of the period for this study, the mid-leaflets of all leaves were removed together with identifying tags, the mid-leaflets measured to indicate leaf areas, and the mean weekly leaf areas for canes and shoots calculated.

This study was repeated during the first 3 weeks of July, 1936. Before the start of this season, the plants were paired on the basis of 1935 responses and re-assigned to the differential treatment groups employed in 1935. The soil moisture levels in 1936, however, were altered to give a maximum of approximately 30 per cent moisture (water free weight basis) for the high level series and a maximum of approximately 16 per cent for the low moisture series. The plants were weighed daily and if the weights indicated the soil moisture to be lower than 28 and 14 per cent, respectively, the weights were brought to the maximum. However, the soil moisture might be reduced as much as 50 per cent

in a single day. Other than the changes just mentioned, the methods for 1935 and 1936 were essentially the same.

Seasonal mean transpiration rates, based on the mean weekly rates for individual plants, in pounds per week per 1000 square centimeters of leaf area, for plants having only shoots, those having only canes, and those having both shoots and canes are presented in the following tabulation:

Duration of Observation	Shoots	Canes	Shoots and Canes
June 10 to July 29, 1935. . .	12.33±0.36	10.81±0.35	9.01±0.35
June 30 to July 21, 1936. . .	16.81±0.68	15.78±0.41	14.71±0.54

Though the transpiration rates per unit of leaf area were greater for shoot foliage than for cane foliage in each of the two seasons, the differences cannot be interpreted as being great enough to account for rather pronounced differences in physiological responses of these two parts of the black raspberry plant.

The transpiration rates for successive weeks for all plants in 1935 in pounds per week per 1000 square inches leaf area were: 7.55, 6.88, 11.25, 11.01, 12.64, 11.91, and 13.14, and those for 1936 were: 13.01, 20.60, and 13.82; those for plants having only shoots in 1935 were: 8.48, 8.87, 14.15, 13.22, 13.35, 12.61, and 13.75, and in 1936 were: 12.20, 20.90, and 14.45. These figures show no definite seasonal trends and such variations as exist are associated with weather conditions to be discussed later.

THE SOIL MOISTURE LEVEL, TRANSPIRATION, AND GROWTH

The seasonal mean transpiration rates (pounds per week per 1000 square inches leaf area) for the 12 plants maintained at each of the soil moisture levels are presented below:

Duration of Observation	Approximate Maximum Soil Moisture (Water Free Basis)		Transpiration Rate	
	High Level (Per cent)	Low Level (Per cent)	High Level	Low Level
June 10 to July 29, 1935	24	17	11.33±0.33	10.10±0.39
June 30 to July 21, 1936	30	16	16.41±0.31	15.21±0.48

The plants growing in soils with high levels of soil moisture did not transpire significantly faster than plants growing in soils with the moisture level varying from 16 or 17 per cent to percentages just above the wilting point. During periods of high temperatures and high sunlight intensity, the tips of lateral shoots often wilted a few hours before watering on the plants growing at either moisture level, but such wilting was much more pronounced for the plants growing at the lower moisture level.

EFFECT OF TEMPERATURE, HUMIDITY, AND SUNSHINE
RELATIONSHIPS

Temperatures and humidities were recorded with a hygrothermograph during the course of the work with excised cane and shoots in 1933, which permitted the calculation of average temperatures and relative humidities for each set of determinations. The coefficient of correlation for temperature and transpiration rate was $.583 \pm .074$ and that for relative humidity and transpiration was negative $.583 \pm .074$. Each of these two factors seem to have played equal parts in accounting for the daily fluctuations in transpiration rates under the conditions of the experiments.

In 1935 and in 1936, when plants in pots were used, weather was not recorded by the writer, but records from the weather bureau station, located about one-half mile from the plants, were used in calculating these relationships. The plants were located in an area about 15 feet wide between two ranges of greenhouses and temperatures were often 3 or 4 degrees higher than those recorded at the weather bureau. The correlations for 1935 are based on weekly averages while those for 1936 are based on daily records. The plants were weighed during the first half of each forenoon, hence the weather bureau records had to be recalculated to correspond to a day beginning at 9:00 a.m. in 1936, and only such plants as were using enough water to make it necessary to add water daily are used in the calculations.

The correlation coefficient for mean temperature and rate of transpiration in 1935 was $.907 \pm .045$ and in 1936 was $.769 \pm .019$, while the correlation for maximum temperature and transpiration rate was $.803 \pm .095$ in 1935 and $.748 \pm .021$ in 1936. The coefficient of correlation for percentage of sunshine and transpiration rate in 1935 was $.512 \pm .188$ and in 1936 was $.809 \pm .053$. No significant correlations were obtained for relative humidity and transpiration rate. This may have been due to the fact that humidity is recorded by the weather bureau at 7:40 and 11:40 a.m. and at 7:40 p.m., which does not permit calculation of average humidity.

These correlations indicate that the daily fluctuations of transpiration rate were determined by both mean and maximum temperatures, relative humidity, percentage of hours of sunshine and possibly other factors. Temperature seems to be the most important of the three factors considered.

There was some indication that the transpiration rates of some determinations were influenced to some extent by total leaf areas of the plants or parts of plants used. However, several correlation coefficients were calculated for leaf area and transpiration rates for the years 1933, 1935, and 1936, and no significant relationships were found.

WATER CONSUMPTION OF PLANTS

The potted plants of the high soil moisture series having both canes and shoots used an average of 34.4 pounds of water per plant during the third week of July, 1935, while the plants of the low soil moisture series consumed an average of 17.6 pounds during that week. During

the second week of July, 1936, the high moisture level plants used 33.3 pounds. Assuming a spacing of 5 by 7 feet in the field and a liberal supply of soil moisture, plants of the size of those of the high soil moisture level in 1936 would use an acre inch of water in about 20 days of hot midsummer weather. These plants, however, were not more than half the size of well grown field plants grown from the same nursery stock in the fourth season of growth.

If the total leaf areas of current season shoots of whole plants may be considered a fair indication of the amounts of new growth made by plants, the plants growing in the soil with the higher moisture level made 77 per cent more growth than the low moisture ones in 1935 and in 1936 when the difference in soil moisture levels was greater, the high moisture soil produced 121 per cent more growth than the low moisture soil.

WEATHER AND GROWTH INCREMENTS

The second week of July, 1936, established a record for high temperatures at East Lansing. During this week the daily maximum temperatures ranged from 96 to 101 degrees F, the percentage of daily sunlight ranged from 83 to 100 per cent and the daily noon relative humidity ranged from 38 to 70 per cent. During this week the average increment per plant for shoot leaf area was 168 square inches compared to 273 square inches for the preceding week and 200 square inches for the succeeding week. Thus it appears that the abnormal conditions of temperature and sunshine, which resulted in a transpiration rate of about 54 per cent higher than the average for preceding and succeeding weeks may have accounted for a diminution of growth rate.

SUCTION PULL

In the report of four years ago the writer reported a suction force for shoot foliage some 37 per cent greater than that for cane foliage as measured by mercury manometers. This study was continued in 1933 when it was found that the method used did not give a true measure of suction pull, but merely indicated the suction pressure at which air was pulled into the plant stems or leaves through lenticels, stomata, or otherwise. At any rate it was found that at the recorded maximum suction pull air came through the stem of the shoot or cane and collected at the severed end forming an air cushion which prevented further intake of water. When the technique was improved to maintain constant contact of the stem end with the water supply, substantially higher readings but no material differences in suction pull for canes and shoots were obtained.

DISCUSSION

Though the three methods employed to study relative transpiration rates of leaves of fruiting canes and current season shoots of the black raspberry give higher transpiration values for the shoot foliage, the differences are not sufficient to account for rather pronounced differences in physiological behavior, such as yellowing of cane foliage, apparent loss of vigor of canes, and failure to maintain the production of large, succulent berries with the advance of the fruiting season.

This study emphasizes rather strongly the relationships between such climatic factors as soil moisture supply, temperature, humidity, and sunshine and plant performance. A liberal and constant supply of soil moisture, accompanied by moderate air temperatures, relatively high humidities and many hours of sunshine, results in the development of abundant and vigorous shoots, which is the first requisite for heavy production the succeeding season. These factors also appear to be essential to the persistence and maintenance of a healthy dark green cane foliage. Finally, this study helps to explain the geography of commercial raspberry growing. The most famous raspberry producing area in the country (Pierce County, Washington) is probably such because of relatively high air humidity, moderate growing season temperatures, a high percentage of possible sunshine in summer, and a rather liberal supply of soil moisture.

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A Chlorosis of Cultivated Blueberries¹

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TWO years ago there appeared in certain portions of plantations of cultivated blueberries at Amherst a chlorotic condition of the plants which seemed to be due to a nutritional deficiency. At first the spaces between the veins of the leaves turned a reddish brown while the veins remained green. As the chlorosis became more serious, the affected areas turned yellow and increased in size until the whole leaf became yellow. In the most severe cases the new shoots from the base of the plant had stunted leaves and both shoot and leaves were entirely yellow. The tip leaves were usually the first to show signs of the trouble. Sometimes about the 4th, 5th, and 6th leaves were the first to show it. Fig. 1 shows one healthy and three chlorotic shoots.



FIG. 1. A, healthy shoot; B, moderately chlorotic shoot; C, severely chlorotic shoot; D, very severely chlorotic shoot.

This chlorosis was observed in the varieties Rubel, Sam, Grover, Cabot, and Pioneer. Rubel seemed to be much more susceptible than the others. In Massachusetts affected plants were found in several plantings in and around Amherst, in one planting in Hanover, and in one in the Cape Cod section. Affected plants were found also in New Brunswick, New Jersey.

This trouble occurred most often in those parts of a field where the soil was low in organic matter and rather dry. There seems to be no

¹Contribution No. 261 of the Massachusetts Agricultural Experiment Station.

direct correlation between this chlorosis and soil reaction, since affected plants were found through a soil pH range of 4.05 to 8.15, and healthy vigorous plants were observed in soils of pH 3.8 to 6.1.

The following treatments were tried in an attempt to overcome the trouble:

In 1935: Manganese sulfate, 1 gram per plant; sodium nitrate, 3 grams per plant; ammonium sulfate, 7 grams per plant; and ferrous sulfate, 0.4 per cent solution sprayed on plants.

In 1936: German peat (GPM) in trenches, $\frac{1}{2}$ bushel per plant; complete blueberry fertilizer (1), 10 grams per plant; magnesium sulfate as Epsom salts, 10, 20, and 30 grams per plant; ammonium sulfate, 28 grams per plant; zinc sulfate, 0.5 gram per plant; and 4-4-50 Bordeaux, sprayed on plants.

So far only those plants which received ammonium sulfate in 1935 have shown signs of recovery. Of the four plants treated three have entirely recovered but the fourth has not yet shown any improvement.

White (2) has reported a similar chlorosis in gardenias. Plants in plots given calcium or sodium nitrate as a source of nitrogen were very severely affected. Plants with ammonium sulfate as a source of nitrogen showed no chlorosis. Chlorotic leaves inoculated with iron compounds responded to the treatment.

The only statement possible at present is that this chlorosis seems to be overcome by an application of ammonium sulfate and that recovery takes about a year.

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Some Effects of Different Storage Temperatures on the Keeping of Cranberries

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THE cost of production and subsequent handling of cranberries probably is higher than that of any of our other important fruit crops. This is not only because of the highly specialized and expensive methods of operation required but also because of the relatively great reduction in yield caused by field diseases and the losses after harvesting from various storage rots and other forms of deterioration. It is estimated that as much as 15 per cent of the harvested crop is lost by spoilage before it is marketed. The largest factor in spoilage is decay in storage resulting from field infection by specific cranberry fungi.

Considerable investigational work has been done in identifying and studying the various species of rot fungi attacking cranberries (1). In all about 40 species have been reported; however, only about eight of these are recognized as important as affecting the berries after they leave the vines. Although much work has been done in determining the fungi which cause loss, and in studying methods of field control, little work has been reported on the relation of loss of fruit in storage to different controlled holding temperatures. It is with this question that this paper mainly deals.

An investigation was started in the fall of 1935 to study the relation of temperature and humidity to keeping quality of cranberries in storage. It is generally recognized that deterioration is favored by unseasonably warm weather such as occurs during the fall and early winter, when it is impossible to keep the stored crop of cranberries at a low enough temperature in the type of common-storage houses generally in use. The usual storage practice is to bring the berries in from the bogs or marshes in open crates with more or less leaves and vines. The berries are stored in this condition and are not cleaned and stored until just previous to shipping to the markets. While most of the storage houses are insulated and provided with some means of ventilation, the temperature within fluctuates with outside conditions. When warm, dry weather occurs after the beginning of harvest the buildings are kept open at night and when practical are closed during the day. Information from such studies as are described herein should be of value to growers who are contemplating the installation of modern cold-storage facilities in their own warehouses or who might use nearby cold-storage plants to reduce the loss sustained under present storage methods and to extend their marketing season over a longer period than is now possible.

MATERIAL AND METHODS

Two commercial varieties, Early Black and Howes, were "milled," that is sorted and graded in the usual commercial manner. These were obtained from Whitesbog, New Jersey shortly after being harvested.

The Early Blacks were obtained on September 18 and were trucked directly to the storage laboratory at Arlington Farm near Rosslyn, Virginia, where on the following day they were put into the various storage chambers in the regulation standard one-quarter barrel shipping box. To insure uniformity in the different lots the berries were carefully emptied onto a large table on arrival and after mixing, the boxes were again filled. The storage conditions were as follows: 30, 32, 36, 40, 50, 60, and 70 degrees F with high relative humidity of 90 to 95 per cent, and 32, 40 and 50 degrees with a medium low humidity of 70 to 75 per cent. The Howes, a late variety, were obtained on September 20, and handled and stored as described for Early Black.

After 2 months' storage one-half of each box was removed for inspection while the remainder was left for an additional 2-month period. The inspection procedure consisted in removing from each box a composite sample of about 600 berries taken from seven equi-distant positions. Each sample was then separated into sound, decayed, and soft berries; and 50 rotten berries from each lot was cultured on corn-meal agar and identification made of the decay fungi present. The different lots of the Howes variety were weighed before going into storage and again after the first 2-month period. The loss in weight in those from 70 and 60 degrees was 9.87 and 8.34 per cent, but for the lower storage temperatures it varied from 2.04 to 3.32 per cent with no consistent relation to temperature. On sound berries determinations were made of the soluble solids, titratable acidity, and hydrogen-ion concentration of the juice, and also crushing tests. No consistent differences between the several lots were found in any of these tests as will be noted in Table I. There is shown however a general increase in acidity and decrease in pH values during storage.

TABLE I—THE RESULTS FROM DETERMINATIONS OF SOLUBLE SOLIDS, TITRATABLE ACIDITY, pH, AND CRUSHING TESTS ON EARLY BLACK CRANBERRIES AFTER 2 MONTHS' STORAGE

Storage		Soluble Solids (Per Cent)	Titratable Acidity (cc N/20 NaOH in 5 cc Juice)	pH	Crushing Test (Pounds)
Temperature (Degrees F.)	Humidity				
70	High	7.59	40.2	2.5	12.4
60	High	7.47	42.2	2.3	12.2
50	High	7.98	41.4	2.4	12.1
50	Low	7.83	41.9	2.9	12.1
40	High	7.70	40.8	2.7	11.9
40	Low	7.86	40.7	2.5	12.9
36	High	7.87	39.7	2.9	12.7
32	High	7.98	39.1	2.5	11.8
32	Low	7.71	40.4	2.5	12.1
30	High	7.80	39.6	2.6	12.0
Before Storage . . .		7.65	36.8	3.1	11.2

The total unmarketable berries in each lot of each variety after 2 and 4 months' storage are presented graphically in Figs. 1 and 2. These graphs differentiate the amount and kind of deterioration that occurred. For convenience five more or less natural groups are estab-

lished as follows: First, the so-called early rotting fungi usually developing early in the storage season or even in the field and including such cranberry fungi as *Acanthorhynchus vaccinii*, *Glomerella cingulata vaccinii*, *Guignardia vaccinii*, and *Pestalotzia guepini*; second, the late rotting fungus *Godronia cassandrae*; third, *Penicillium* species, which are not specifically cranberry rots; fourth, "all others," a group including a number of fungi of occasional occurrence; and lastly, physiological breakdown. This last group includes two types of breakdown. At all temperatures above 32 degrees there occurred a certain number of soft withered berries that always proved to be sterile when cultured, a condition apparently due to senescence, while at 32 and 30 degrees, and to a slight extent at 36 and 40 degrees, there was a different type of breakdown characterized by a rubbery texture. In these berries the color was somewhat light, the luster of normal berries was lacking, and the pigmentation of the epidermis had become diffused into the pulp. The taste and appearance were not unlike those of frozen berries. Practically no senile breakdown was found at these lower temperatures.

RESULTS WITH THE EARLY BLACK VARIETY

In Fig. 1 is illustrated the results with the Early Black variety. There was a general increase in all types of breakdown after 4 months as compared to 2 months. The "all others" group shows no particular relation to temperature. *Penicillium* occurred mostly at 70 degrees during the 2-month storage period, but after 4 months it was found in increased amount at this temperature and also at the other higher temperatures. It was negligible at all the lower temperatures. The so-called early rotting group was of relatively minor importance; however, it occurred in greatest amount at the higher temperatures, but there was an appreciable increase after 2 months' storage only at 70 degrees. The late-rot fungus *Godronia* was responsible for the greatest amount of decay in this variety and increased appreciably during the second 2 months of storage. In a general way this organism seemed to be present in greatest amount in lots stored in the temperature range from 60 to 36 degrees and was especially destructive at 50 degrees with high humidity. There was an increase in physiological or senile breakdown during the second 2 months at temperatures above 32 degrees. To some extent this would be expected but there was an unaccountably large increase at 40 degrees with low humidity. At both inspections there was shown a marked amount of sterile breakdown at 32 and 30 degrees which, as has been explained, is of a different nature than that occurring at higher temperatures. This type might be described as low temperature breakdown. It included at the first inspection 13 per cent of the berries at 32 degrees with low humidity and 37 and 71 per cent of those at 32 degrees and 30 degrees with high humidity, respectively, and at the second inspection this amount had increased to the surprisingly large amount of from 73 to 77 per cent of the total quantity stored at these same three temperatures.

RESULTS WITH THE HOWES VARIETY

In Fig. 2 is shown the results with the Howes variety. This is considered by some to be a better keeping variety than the Early Black

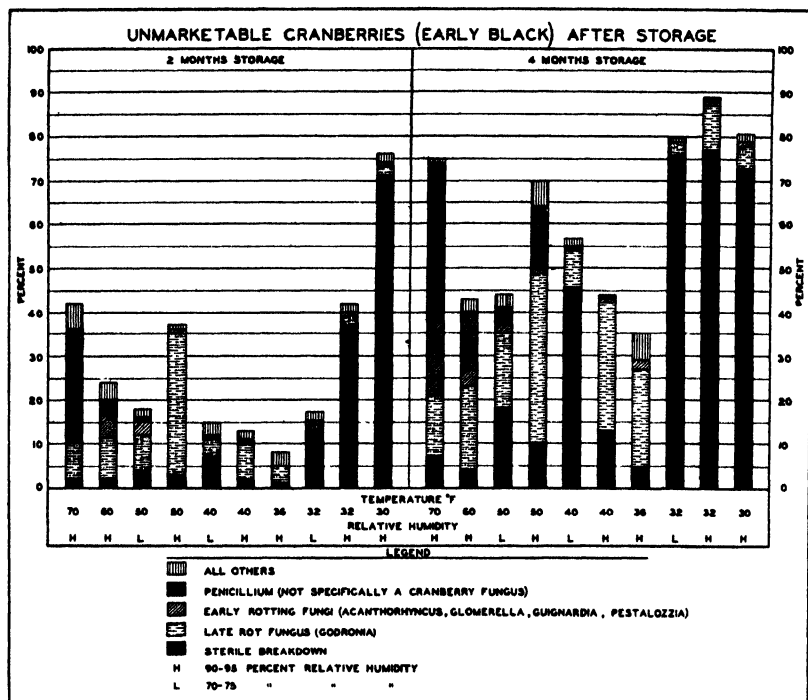


FIG. 1. Unmarketable Cranberries (Early Black) after storage.

but the results obtained in these particular tests did not altogether substantiate this belief. The percentage of overripe or senile berries found after 2 months' storage at temperatures of from 70 to 36 degrees appeared to be slightly greater than in the Early Black variety while the sterile berries showing breakdown at 32 and 30 degrees, on the other hand, did not show as great an amount although at 30 degrees there was enough of this sterile breakdown (30 per cent) to be important. After 4 months' storage the extent of this breakdown found at 32 and 30 degrees was significant but was not so marked as in the early variety. Late rots on the whole were not so prevalent in the Howes variety as in the Early Black. Penicillium was only found in significant amount after 2 months' storage at 70 and 60 degrees but after 4 months it was present in a considerable amount at as low temperature as 40 degrees. In general this rot seemed to be more prevalent in this variety than in the Early Black. The "all others" group of rot fungi also seemed to be more prevalent in this variety. No very consistent temperature differences were apparent.

CONCLUSION

Of the temperatures used in this experiment 36 degrees F proved to be the most suitable for preserving the berries in a marketable condition over a 4-month storage period. At the conclusion of the test it was found

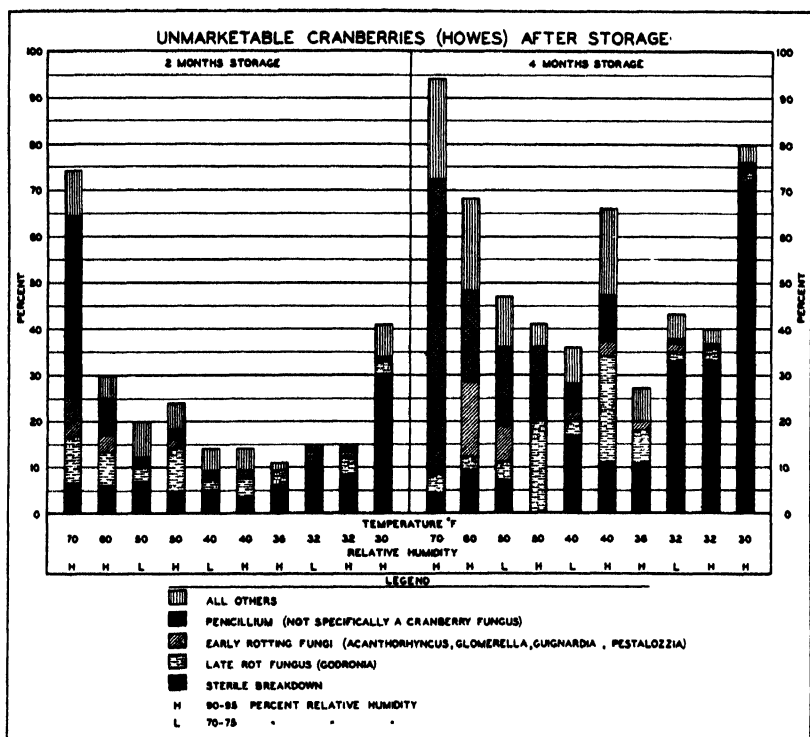


FIG. 2. Unmarketable Cranberries (Howes) after storage.

that 65 per cent of the Early Blacks and 73 per cent of the Howes stored at this temperature were in excellent condition for marketing. The test further indicates that for a shorter storage period of 2 months somewhat higher and lower temperatures may be safely used.

Some striking differences in keeping quality were apparently influenced by humidity. A medium humidity of 70 to 75 per cent as a rule favored better keeping of the berries but this was not always the case. Temperatures below 36 degrees suppressed decay to a remarkable extent, but there was heavy loss of berries due to the low temperature breakdown, and this seems to preclude the use of temperatures as low as 32 and 30 degrees.

As to color and general appearance the berries stored at 36 and 40 degrees were most attractive. From 36 degrees upward the color tended to darken and the amount of red increased. Berries stored at 50 degrees and above were of solid color and somewhat darker than is desired by some markets.

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Pollination and the Setting of Fruit in the Black Corinth Grape

By H. P. OLMO, *University of California, Davis, Calif.*

THE dried, seedless berries of the Black Corinth¹ grape, a variety of *Vitis vinifera*, constitute a class of raisins known and sold in world commerce as "currants." The small, spherical berries are typically without traces of seed development, hence parthenocarpic. According to Pearson (4) there is no ovule development beyond the time of bloom and the parthenocarpy is attributed to defective embryo sac formation, some or all of the nuclei degenerating. The pollen is viable and can fertilize normal embryo sacs, Pearson (4), Stout (6). Observations at Davis for the past 3 years show that abundant pollen is produced and many grains are deposited on the stigmatic surface.

The present study was undertaken to demonstrate whether the parthenocarpy is vegetative or stimulative. Is pollination necessary for fruit formation? A complicating factor exists, since in the culture of this variety girdling is universally practiced. This consists in removing a narrow strip of bark from around the canes or trunk shortly after blossoming, so as to afford the developing ovaries a better nutrition. Obviously, then, the important question is whether the stimulus afforded by girdling is sufficient to give a normal fruit-set in the absence of pollination.

In 1934, no girdling was practiced. A preliminary experiment with two 7-year-old vines indicated that flowers emasculated and then bagged, either with or without pollination, failed to set fruit (Table I). Other clusters on the same vines left to blossom naturally only had a few isolated berries at harvest time. Many were larger than the typical berry and had some seed development. Most of the clusters abscised 3 or 4 weeks after full bloom. Pollinated ovaries on cluster 5 (Table I) appeared to be slightly larger in size than unpollinated ones, but even they did not enlarge more than $2 \times 3\frac{1}{2}$ mm.

The 1934 results indicated that girdling was apparently necessary before any appreciable setting of fruit could be obtained, so in 1935 four clusters on the same vines were emasculated and the canes girdled 3 days later. Not a single fruit set. Clusters blossoming naturally on canes that were girdled set very well. The objection might be raised that either the emasculation or the bagging resulted in injury to the ovaries. This was unlikely since the treated clusters were shaded and the bags partly cut away after the receptive period of the ovaries had passed. Although the ovaries failed to appreciably increase in size, they remained healthy and turgid for approximately 1 month after emasculation.

During 1936, 13 clusters were emasculated (Table I). Of these, clusters 10, 11, and 12 were pollinated and girdled; clusters 13, 14, 15, 16 were girdled without pollination; clusters 17, 18, 19, 20 were left without treatment; and clusters 21 and 22 were only pollinated. On June 16, about 1 month after treatment, the ovaries still alive were

¹Also called Panariti or Zante Currant.

TABLE I—EFFECT OF POLLINATION AND GIRDLING ON THE SETTING OF FRUIT IN THE BLACK CORINTH GRAPE

Year	Date	Cluster	Flowers Emascu- lated	Treatment	Berries Har- vested August 20	Observations
1934	April 30	1	138	None	0	Vines were very vig- orous. No crop was obtained, ex- cept for a few iso- lated berries hav- ing some seed de- velopment. Most clusters abscised.
	May 1	2	293	None	0	
	May 1	3	69	None	0	
	May 1	3	52	Pollinated	0	
	May 1	4	102	None	0	
	May 1	4	60	Pollinated	0	
	May 1	5	145	None	0	
	May 1	5	20	Pollinated	0	
1935	May 21	6	302	Girdled	0	Control clusters on girdled canes set a good crop.
	May 21	7	284	Girdled	0	
	May 21	8	293	Girdled	0	
	May 22	9	307	Girdled	0	
1936	May 14	10	264	Pollinated and girdled	196	Very good berry set.
	May 19	11	359	Pollinated and girdled	286	Very good berry set.
	May 22	12	345	Pollinated and girdled	211	Very good berry set.
	May 14	13	261	Girdled	0	Cluster abscised.
	May 15	14	185	Girdled	79	15 berries had very small seeds.
	May 15	15	116	Girdled	0	Cluster forms ab- scised two to three weeks after emasculatation.
	May 16	16	292	Girdled	0	
	May 14	17	231	None	0	
	May 15	18	205	None	0	
	May 16	19	143	None	0	
	May 16	20	201	None	0	
	May 14	21	202	Pollinated	0	114 ovaries counted on June 16
	May 19	22	198	Pollinated	0	

counted. Cluster 20 retained eight small green ovaries which showed little increase in size. All clusters of the unpollinated series, with the exception of cluster 14, had dried up and many had abscised. The exceptional cluster 14 contained 79 berries showing a large range in size, and 15 of the larger berries were found to contain miniature seeds. Cluster 22, that had been pollinated but not girdled, retained 114 ovaries. Examination of the cane disclosed that the base had become twisted, effecting a partial girdling. These fruits did not live to maturity.

Examination of the data indicates that girdling as well as pollination are necessary to insure a satisfactory yield of fruit at Davis. Pearson's (4) failure to obtain any set after emasculating, pollinating, and bagging many clusters is logically explained by the absence of a sufficient nutritional stimulus, since girdling was not practiced. However, she states that "four clusters on ringed shoots which were emasculated set perfectly"—presumably without pollination. In the present experiment, only one cluster out of eight formed berries without pollination and this did not approach a satisfactory set. As stated before, some of the

berries were enlarged and had some seed development. As every precaution was taken to eliminate chance pollination, this is adequate proof that under some conditions partial development of the seeds may occur apogamically. The largest seeds so formed did not exceed 20 mgs. in air-dry weight, compared to approximately 45 mgs. for fully developed seeds of this variety, Roussopoulos (5), yet the seed coats of some were sufficiently hardened to be objectionable for making seedless raisins. No endosperm or embryo development could be detected.

It is known that girdling of the Black Corinth was not practiced in Greece much before 1833, Viala and Vermorel (7), yet Burlumi (1) gives instances that show currants of this variety were already in commerce as early as the latter half of the fourteenth century. Obviously fairly good crops must have been obtained without girdling. Either the vines themselves or the conditions under which they were grown differed in some important respects from those now found in California. Husmann (2) reported on girdling experiments conducted at Fresno, California, and stated "It has been found that in order to make the blooms set and secure full yearly crops of grapes the vines must be ringed every year." Likewise, Jacob (3) obtained only small yields on ungirdled check vines. Practically all of this fruit was unmarketable, the berry size was too small and the clusters ragged.

SUMMARY

The seedless Black Corinth grape requires the stimulus of pollination, as well as a nutritional stimulus supplied by girdling, in order to obtain a satisfactory set of fruit.

Some berries may occasionally develop without pollination, but such vegetative parthenocarpy is exceptional and cannot be relied upon for a satisfactory set of fruit, even though girdling is practiced.

Partial seed development may occur apogamically, but no endosperm or embryo development can be detected in such miniature seeds.

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The Composition of Grape Juice as Affected by the Method of Vine Training¹

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AS reported in a previous paper (1), a study was made of the chemical composition of grape juice samples prepared from some 30 varieties of grapes grown at Henryetta, Oklahoma. These data included figures for 1 year (1934) that were secured by averaging the results of three separate analyses made on samples secured from grapes grown on canes from the top and bottom wires of the Kniffin trellis, and from the Munson trellis. This paper presents detailed data prepared from that series of analyses and later analyses as indicated.

The following year samples were secured in a similar manner from varieties grown on the Kniffin trellis, the vineyard being located on

TABLE I—CHEMICAL COMPOSITION OF GRAPE JUICES, HENRYETTA, 1934 SELECTED VARIETIES

	Sugars (Per Cent)		Acidity (Per Cent)	Astringency (Grams per Liter)			Density (15.6 Degrees C)	Acid: Sugar Ratio
	Reducing	Total		Total	Non- Tannins	Tannins		
Concord								
*K.T.	10.00	10.51	.684	1.875	.737	.938	1.0579	1:15.4
K.B.	9.51	9.75	.651	2.018	.937	1.081	1.0569	1:15.0
M.	10.37	11.09	.746	1.921	1.033	.888	1.0599	1:14.9
Extra								
K.T.	12.17	12.63	.406	.927	.802	.125	1.0685	1:31.1
K.B.	12.37	12.54	.387	.885	.844	.041	1.0673	1:32.4
M.	12.42	13.08	.412	.869	.761	.108	1.0723	1:31.7
Bailey								
K.T.	12.30	13.06	.527	1.050	.906	.144	1.0689	1:24.8
K.B.	12.50	12.97	.523	1.050	.885	.165	1.0670	1:24.8
M.	12.46	13.23	.536	1.133	.925	.208	1.0696	1:24.7
President								
K.T.	9.40	10.10	.614	3.398	1.771	1.627	1.0585	1:16.4
K.B.	10.00	10.55	.608	3.380	2.039	1.341	1.0617	1:17.4
M.	9.37	9.63	.568	2.902	2.162	.740	1.0568	1:17.0
Niagara								
K.T.	10.81	11.06	.606	1.646	.890	.756	1.0577	1:18.3
K.B.	9.52	9.69	.608	1.482	.761	.721	1.0556	1:15.9
M.	10.27	10.27	.557	1.500	.865	.635	1.0542	1:18.4
Averages of 22 Samples (Including the Above Figures)								
K.T.	11.14	11.65	.622	1.772	1.078	.690	1.0652	1:19.6
K.B.	10.96	11.43	.613	1.665	1.041	.620	1.0658	1:19.7
M.	11.22	11.69	.606	1.774	1.058	.716	1.0659	1:20.4

*K.T. = Kniffin trellis top wire.

K.B. = Kniffin trellis bottom wire.

M. = Munson trellis.

¹Published with the approval of the Director of the Oklahoma Agricultural Experiment Station.

the Perkins farm of the Oklahoma Experiment Station. The growth conditions here are different from those mentioned in the previous paper for the soil is a fine sand as compared to the heavy silt loam found at Henryetta.

Procedure for preparing the samples and chemical methods are described in a previous paper (1), the only variation being that the juice prepared from the Perkins samples was prepared the same day that the samples were collected, and not after the grapes had been held overnight as was the procedure with the samples from Henryetta.

Varieties sampled from Henryetta included America, Bailey, Beacon, Bell, Captivator, Carman, Cloeta, Concord, Diamond, Extra, Fern Munson, Lenoir, Lomanto, Lutie, Moore Early, Muench, Niagara, President, Salamander, Winchell, Worden and Xlanta.

Those from Perkins included America, Armalaga, Bailey, Beacon, Caco, Captivator, Carman, Catawba, Cloeta, Delaware, Diamond, Extra, Fern Munson, Goethe, Golden Muscat, Herbemont, Martha, Mathilda, Mericadel, Muench, Niagara, Pockington, Rommel, Urbana and Wine King.

Table I shows analyses of selected varieties from Henryetta and averages of the chemical determinations on the juices from 22 varieties for each location. Table II shows similar data for the samples prepared from grapes grown at Perkins. Group averages are for 25 varieties.

An inspection of the data given in Tables I and II, shows no significant difference in the chemical composition of samples of grape juice

TABLE II—CHEMICAL COMPOSITION OF GRAPE JUICES, PERKINS,
1935 SELECTED VARIETIES

	Sugars (Per Cent)		Acidity (Per Cent)	Astringency (Grams per Liter)			Density (15.6 Degrees C)	Acid: Sugar Ratio
	Reducing	Total		Total	Non- Tannins	Tannins		
Extra								
K.T.	12.73	13.20	.621	.906	.682	.224	1.0684	1:21.1
K.B.	12.55	12.55	.678	.798	.682	.116	1.0676	1:18.5
Bailey								
K.T.	12.37	12.37	.686	1.268	.896	.372	1.0664	1:18.0
K.B.	12.30	12.75	.807	1.258	1.012	.246	1.0691	1:15.8
Niagara								
K.T.	10.99	11.31	.675	1.147	.771	.376	1.0678	1:16.8
K.B.	11.54	11.76	.638	1.090	.792	.298	1.0642	1:18.4
Diamond								
K.T.	17.17	17.67	.566	1.208	.713	.495	1.0933	1:31.2
K.B.	16.25	16.87	.636	1.268	.771	.497	1.0788	1:26.5
Muench								
K.T.	12.00	13.20	.550	1.619	.767	.852	1.0733	1:24.0
K.B.	11.04	11.95	.562	1.513	.682	.831	1.0687	1:21.3
Averages of 25 Samples (Including the Above Figures)								
K.T.	11.96	12.45	.616	1.193	.839	.386	1.0699	1:21.5
K.B.	12.08	12.44	.645	1.224	.866	.390	1.0710	1:20.9

prepared from grapes produced from canes growing upon the top and bottom wires of the Kniffin trellis and those from the Munson trellis.

A study of the detailed analyses, too comprehensive to be included in these tables, further confirm this conclusion, for although figures for individual samples do vary, they do so in no consistent manner nor in any predictable direction.

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Injury to the Buds of Grape Varieties Caused by Low Temperatures¹

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THE cold winters of 1933-34 and 1934-35 resulted in various types of winter injury to certain fruit plants in New Jersey. Some grape varieties had a rather large proportion of fruit buds killed so that there was an opportunity to secure information on varietal resistance to low temperatures.

OBJECTIVES

A systematic study of the bud injury on different varieties was undertaken for the following reasons. Information as to relative hardiness of commercial varieties would be of value in making recommendations for planting. Similar information on a rather large number of less well known varieties should be helpful to plant breeders working to produce hardy varieties. It would be desirable to know whether bud injury affects the yields of certain varieties even following mild winters. Definite information on the relative susceptibility of the primary, secondary, and tertiary buds of the compound fruit bud to injury by low temperature would be of value.

REVIEW OF LITERATURE

There are a number of references in the literature to the resistance of grape varieties to low temperature. Most of these references discuss killing of canes or entire plants rather than killing of buds.

Gladwin (3) has recorded the percentage of injury to buds of a long list of grape varieties during the winter of 1915-16. His figures, however, are based on the percentage of buds growing and it is possible that some of the buds listed as having been killed remained dormant instead. Angelo (1) showed that on certain varieties there were many dormant buds which might be forced into growth if the earlier developed shoots were killed by frost. Gladwin (3) discussed the relative productiveness of shoots arising from primary, secondary and tertiary buds. Wiggans (5) found that shoots from primary buds were roughly three times as productive as shoots from secondary buds.

It has been brought out by Gladwin (3) and others that the relative maturity of the canes is of considerable importance in determining hardiness of the grape. Saunders (4) in 1883 wrote that "For all cultural purposes it is sufficiently accurate to assume that the hardiness of a grape simply depends upon its immunity from mildew." There are undoubtedly many factors associated with hardiness in the grape and indeed many types of hardiness, as recently brought out by Blake (2), who was dealing particularly with the peach.

In these investigations there has been no effort to make a complete study of hardiness in the grape but only to report on the bud injury

¹Journal Series paper of the New Jersey Agricultural Experiment Station, Department of Pomology.

sustained by different varieties in the vineyard on the Horticultural Farm at New Brunswick. This vineyard is located at an elevation of approximately 90 feet. The soil is a well drained Sassafras loam merging into a gravelly phase. The varieties were all given the same cultural treatment and individual vines were pruned according to the amount of growth they had made. Growth and production of most varieties have been fairly good from year to year.

The winters of 1933-34 and 1934-35 each included one especially cold night. On February 9, 1934, the temperature fell to -16 degrees F and on January 28, 1935 the temperature dropped to -14 degrees F. There were no long periods during either winter when the temperature was high enough to start cell growth. The injury recorded, therefore, may presumably be attributed to the effects of low temperature, probably that occurring on the nights mentioned.

The taking of records was continued during 1936 in order to secure data following a comparatively mild winter. The minimum temperature for 1935-36 was -4 degrees F which occurred on January 23 and again on February 20.

PROCEDURE

Early in March of each year selected canes were taken indoors for examination. The canes secured were apparently well matured and were of the type that would normally be used for renewal at pruning time. The small buds at the base of the canes were discarded as were the buds near the tips. One hundred of the selected compound buds from each variety were examined after being sectioned transversely with a razor blade. The injured parts within the compound bud were easily distinguished by their brown color. Due to the brown pubescence inside the bud scales it was sometimes necessary to make several slices with the razor blade before the condition of the bud could be accurately determined. Injured buds had both vegetative growing point and flower primordia killed. Sterile shoots, therefore, would ordinarily arise from a secondary or tertiary bud rather than from a primary bud in which the primordia had been killed.

RESULTS

Data pertaining to certain varieties are included in Table I with the combinations of injured and uninjured buds grouped into six classes. Other combinations not classified in the table occurred less frequently. Where the numbers recorded for a variety do not total 100, the difference is due to these other combinations of injury. Golden Muscat, for instance, had 40 per cent of its compound fruit buds with secondary and tertiary buds dead (primary alive) in 1935, and 27 per cent in 1936. In the case of most other varieties, nearly every compound bud that was injured at all had the primary dead. With most varieties the primary was definitely more susceptible to low temperature than either the secondary or tertiary.

CLASSIFICATION OF VARIETIES

The fact that the buds of certain varieties were only slightly injured even in 1935 whereas others were severely injured is shown in Table I.

TABLE I—CONDITION OF GRAPE BUDS, HORTICULTURAL FARM,
NEW BRUNSWICK, N. J.

Variety	Entire Compound Bud Alive	Primary Dead	Primary and Secondary Dead	Primary and Tertiary Dead	Secondary Dead	Entire Compound Bud Dead
<i>March, 1934</i>						
Agawam	26	8	0	26	0	40
Beta	94	6	0	0	0	0
Brocton	90	6	0	0	0	4
Concord	96	4	0	0	0	0
Daisy	96	2	0	0	0	2
Dutchess	34	30	0	20	0	16
Fredonia	92	8	0	0	0	0
Golden Muscat	90	4	0	6	0	0
Lucile	90	8	0	2	0	0
Moore Early	96	2	0	0	0	2
Niagara	85	9	0	6	0	0
Sheridan	88	6	0	0	0	6
Wilder	82	12	0	0	0	6
Worden	100	0	0	0	0	0
<i>March, 1935</i>						
Agawam	0	22	12	21	0	44
Beta	84	2	2	0	10	1
Brocton	31	52	1	0	3	13
Concord	63	15	1	3	11	2
Daisy	100	0	0	0	0	0
Dutchess	4	10	4	9	1	71
Fredonia	91	4	0	0	5	0
Golden Muscat	9	0	0	1	0	50
Lucile	95	5	0	0	0	0
Moore Early	97	3	0	0	0	0
Niagara	30	20	0	1	6	43
Sheridan	80	13	0	4	0	3
Wilder	16	12	1	0	15	55
Worden	98	1	0	0	1	0
<i>March, 1936</i>						
Agawam	90	8	1	1	0	0
Beta	100	0	0	0	0	0
Brocton	93	3	0	0	0	1
Concord	92	3	0	0	1	1
Daisy	100	0	0	0	0	0
Dutchess	91	5	0	0	1	3
Fredonia	58	24	2	2	6	4
Golden Muscat	55	0	0	0	4	13
Lucile	97	3	0	0	0	0
Moore Early	94	4	0	2	0	0
Niagara	86	6	0	3	4	0
Sheridan	96	2	0	0	1	1
Wilder	97	3	0	0	0	0
Worden	91	6	0	0	1	2

Since records were secured each year on a large number of varieties, the complete data would be too lengthy to include in detail. The varieties can be grouped, however, to indicate their relative bud hardiness. This grouping is based on the percentage of primary buds uninjured as that is undoubtedly the most important from the standpoint of production.

Class A, 1934:—Varieties with more than 66 per cent of primary buds alive: Adams, America, Beta, Brighton, Brocton, Catawba, Clin-

ton, Clevener, Concord, Daisy, Delaware, Diamond, Dunkirk, Eclipse, Fredonia, Green Mountain, Golden Muscat, Iona, Ives, Lindley, Lucile, Melton, Merrimac, Moore Early, Niagara, Noah, Ontario, R. W. Munson, Riparia Gloire, Ripley, Salem, Sheridan, Wilder, Worden.

Class B, 1934:—Varieties with 34 to 66 per cent of primary buds alive: Campbell Early, Champion, Dutchess, Empire State, Eumelan, Highland, Mericadel, Pontiac, Portland, Urbana, Vergennes, Watkins, Wayne.

Class C, 1934:—Varieties with less than 34 per cent of primary buds alive: Agawam, Armalaga, Brilliant, Ellen Scott, Hanover, Stout Seedless.

Class A, 1935:—Varieties with more than 66 per cent of primary buds alive: Adams, Beta, Caco, Catawba, Campbell Early, Clevener, Clinton, Concord, Daisy, Delaware, Diamond, Dunkirk, Fredonia, Green Mountain, Iona, Ives, Lucile, Moore Early, Noah, Riparia Gloire, Sheridan, Worden.

Class B, 1935:—Varieties with 34 to 66 per cent of primary buds alive: Brighton, Brilliant, Brocton, Eumelan, Golden Muscat, Hanover, Highland, Melton, Merrimac, Niagara, Ontario, Pontiac, Portland, Ripley, Salem, Urbana, Watkins, Wayne.

Class C, 1935:—Varieties having less than 34 per cent of primary buds alive: Agawam, Armalaga, Champion, Dutchess, Ellen Scott, Empire State, Lindley, Stout Seedless, Vergennes, Wilder.

In 1936, following a mild winter, the same varieties were examined and most of them had more than 66 per cent of the primaries alive. Therefore, only Classes B and C will be given.

Class B, 1936:—Varieties having 34 to 66 per cent of primary buds alive: Armalaga, Bailey, Melton.

Class C, 1936:—Varieties having less than 34 per cent of primary buds alive: Stout Seedless.

If the varieties were classified according to species there would be found a great variation in bud hardiness within the species. This agrees with the observations of Gladwin (3).

INJURY TO VITIS VINIFERA

In the course of these investigations examinations were made of the buds of a number of varieties of *Vitis vinifera* most of which had been surviving the winters, unprotected, and with little or no injury, previous to 1933–34. In 1934, however, there was a complete bud kill on the following varieties: Bellino, Black Monukka, Corinthe Rose, Foster, Frankenthal Precocce, Gros Sapot, Tokay, Lignan Blanc, Pedro Ximines, Purple Damascus, Rose de Italia, Trentham Black and White Luglienga. Two varieties, Chasselas Rose de Falleau and Madeline Celine were the only ones to have some live buds but even these varieties produced very little fruit.

In 1935 there was a practically complete kill of all buds on all *vinifera* varieties.

In 1936 there were some buds alive on all *vinifera* varieties except Tokay and Rose de Italia but very little fruit was produced except by Madeline Celine and Chasselas Rose de Falleau.

RELATION OF BUD INJURY TO GROWTH AND PRODUCTION

In most cases the wood of the canes examined seemed to be less susceptible to injury than the buds. Wood that was apparently uninjured was quite often found between nodes where all the buds were killed and only a few varieties, except the *viniferas*, showed any definite injury to canes at the time the buds were examined. It is recognized, of course, that there were some variations in wood maturity between different varieties even under the same cultural conditions.

No attempt has been made to definitely correlate yield records with the percentage of bud injury. It was quite evident, however, that a comparatively large number of buds could be killed without greatly reducing the crop below what would be expected from a normal, uninjured vine. Observations made each summer and compared with the results of the bud examinations of the previous March indicate that, on many varieties, a considerable number of uninjured buds may remain dormant. When there are a large number of buds injured, however, some of the buds which would otherwise remain dormant may be forced into growth. Furthermore, the killing of a few buds may have somewhat the same effect as thinning and may result in larger clusters from the buds that are left. It would require considerable study to determine just what percentage of the buds could be killed without materially affecting the total yield. In some cases, however, certain varieties have produced a good commercial crop, when as many as 33 per cent of the primary buds were killed.

From the data secured in 1936, it would seem that very few varieties survive such winters with 100 per cent of the buds uninjured even though the temperature was no lower than -4 degrees F. This may be a factor in crop production during some years when no winter injury is suspected, especially when unproductive shoots from secondary buds give the vine an appearance of normal growth. Maturity of the buds may have an important bearing on their ability to survive during mild winters but since the extent of winter injury is usually affected by the maturity of the tissues, it would be difficult, if not impossible, to distinguish between injury due primarily to cold and that due to tissue immaturity. The important thing is the ability of a variety to survive with a minimum of any kind of injury.

SUMMARY

A number of grape varieties are classified according to the percentage of primary buds alive after minimum temperatures of -16 , -14 , and -4 degrees F. With most varieties the primary bud was more susceptible to injury by low temperature than was the secondary or tertiary. Buds of most varieties of *Vitis vinifera* were killed during the winter of 1935-36 by a temperature of -4 degrees F. The wood of grape canes was generally more resistant to injury from low temperatures than were the buds. There was considerable injury to buds of some varieties during the winter of 1935-36 when the minimum temperature was -4 degrees F. The yield, however, was not greatly affected in some cases even when as many as 33 per cent of the primary buds were killed.

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Breeding Hardy Grapes

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FROM the standpoint of this paper hardiness means something far more than is ordinarily thought of in connection with grapes. Varieties such as Concord, Worden, Delaware, Brighton and the other well known varieties of Eastern United States would be listed as tender in our classification. Named varieties which have sufficient hardiness to live and ripen a crop a reasonable percentage of the years at Fargo, North Dakota, are limited to such ones as Beta, Alpha, Monitor, Dakota and Hungarian. Even these can hardly be classed as wholly satisfactory, inasmuch as in many years they kill to the ground at Fargo, and farther west in the State rarely produce a crop. It is evident, therefore, that for this territory we must have hardier grapes than these.

Fortunately, *Vitis vulpina* is native to North Dakota and withstands the winters without injury. Plants of this species have been found as far north as the Riding Mountains of Manitoba. This material would therefore seem to supply the needed hardiness. Hedrick says that, "*riparia*¹ has always been considered of great promise in the evolution of American grapes. It can hardly be said that it fulfilled expectations" (3). Nevertheless, among the leading varieties described in "The Grapes of New York," 32 are claimed to have it as an ancestor. This is not a bad record when it is realized that these varieties gained a foothold in regions where *labrusca* is hardy.

Since Beta was claimed to be a cross between Concord and the wild grape of Minnesota, and Alpha is nearly identical, a considerable number of seedlings of these were raised at the North Dakota Agricultural Experiment Station hoping that their seedlings might provide the needed combination of hardiness and quality. However, all of the seedlings of both Beta and Alpha proved to be very similar to these varieties and did not show segregation into the various types that might be expected if Beta was actually a cross. W. H. Alderman reports similar results at Minnesota.

Controlled crosses were next made between native *Vitis vulpina* and the cultivated varieties Concord and Eclipse. From these crosses the F₁ generation was intermediate in fruit. The plants were hardy enough to live through part of our winters without cover. None, however, proved to have any commercial value. An F₂ generation was therefore grown. Following the winter of 1935-36, one of the coldest on record, 139 of these plants set fruit. Of this number more than half lost their crop in the record breaking heat of the summer of 1936, leaving 67 to mature. Unlike Alpha and Beta seedlings, these varied widely in important respects. The colors of the fruit were purple and white; size ranged from that of the common wild *vulpina* to that of Eclipse, which is only slightly smaller than Concord; the flavor varied from very acid to

¹*Vulpina* has since superseded *riparia* as a name of this species.

mild and sweet ; and bunches varied from compact to extremely open. None of those which ripened fruits had foliage other than glabrous or nearly so. In fact, few plants, fruiting or not, showed much pubescence. From a genetic standpoint it is realized that this material does not lend itself to careful analysis because nearly half the plants were winter killed and had disappeared before reaching bearing age. Many more were hurt so badly that they did not bloom. Nevertheless, the variability of the progeny follows what might be expected with a normal Mendelian segregation. The fact that seedlings of Beta failed to show segregation, though the reputed parentage of Beta is the same, leads one to agree with Hedrick (2), and with Brierley and Alderman (1) that Beta is probably not a hybrid.

From among the 67 fruiting survivors of the *vulpina* x *labrusca* hybrids, several selections were made which would seem to have some possibility as worthwhile horticultural varieties. Whether they may be adapted to more unfavorable conditions than our present recommended commercial varieties, remains to be proven. Again whether these particular seedlings are of value or not is of much less importance than the fact that they indicate the probability that with a larger number of seedlings desirable combinations may be secured which will permit grape growing over a wider area.

Whether Alpha (the wild seedling of Brother William, Collegeville, Minnesota) ; or Beta, Monitor, Suelter and Dakota (the products of Louis Suelter, Carver, Minnesota) (4) are *Vitis vulpina* may perhaps be worthy of investigation. The flavor of the fresh fruit and its cooked products do not indicate *vulpina*. Alpha and Beta, while of different origins, are nearly identical in fruit and plant. Both come from the same general region in Minnesota. These facts suggest the possibility that they may be representatives of a distinct species, or if not that, then perhaps a botanical variety of *vulpina*.

As a source of seedlings from named varieties, Hungarian is suggested as offering possibilities. While it is reported to have come from Hungary, according to a letter from H. P. Gould of Washington, the plants growing on the North Dakota Agricultural Experiment Station grounds give unmistakable evidence of *labrusca* ancestry in plant and fruit characteristics, and its hardiness suggests *vulpina* parentage. Its resemblance to Janesville, a Wisconsin *labrusca-vulpina* hybrid, is striking. They may perhaps be identical.

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Breeding for Hardy Seedless Grapes

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SINCE 1919 the writer has cooperated with the Department of Pomology of the New York State Agricultural Experiment Station at Geneva, New York, in a project the principal aim of which is to develop hardy seedless grapes of value for culture in a climate such as that of central New York. In connection with the breeding efforts, studies were made of the nature and scope of the various types of seedlessness in grapes and of the relation of various other conditions which affect the production of fruit. A report on this aspect of the research has recently been published (12). The present paper will summarize the results of the breeding efforts in somewhat more detail than has previously been done (9, 10, 11, 12, 13, 14). But this report must of necessity be largely a report of progress for a large proportion for the seedlings have not yet fruited.

The first step in this breeding project was the use of various seedless grapes as pollen parents in crosses with hardy seeded varieties and selected seedlings grown at the State Experiment Station at Geneva. It was soon found (9, 10, 11) that some seedlings of the F_1 generation of certain combinations of *seeded* x *stenospermocarpic* seedless bear *stenospermocarpic* fruit. There are both seeded and seedless among the F_1 progenies, at least for various crosses. The next step was, and still is, the use of the best of these seedlings for crosses among themselves in such combinations as *seeded* x *seeded* and *seeded* x *seedless* for later generations and also for back crosses with the original seedless types. By crossing plants which have different seedless parents various combinations of ancestry are obtained. Thus later generations are obtained in which more seedless plants appear and the best of these are then used in further breeding.

A general survey of the extent of the breeding work to date is as follows: About 250 different combinations have been effected; about 20,000 seeds have been obtained of which less than half germinated. Many young seedlings died in the nursery and others which are weak or tender died in the vineyard. About 1,000 of the seedlings have fruited and of these 84 are seedless or near-seedless. There are numerous seedlings especially of the more recent breeding that are yet to bear fruit.

THE PROGENIES DERIVED FROM THE CORINTH GRAPES AS POLLEN PARENTS

The Black Corinth, the clone called Panariti, and White Corinth were employed in about 25 different combinations with hardy seeded grapes and over 500 seedlings were obtained of which a considerable number have fruited. Nearly all of these plants produced seeded fruits only. Several had clusters composed of large seeded berries and smaller seedless berries. It was determined experimentally that one of these plants is able to produce seedless fruits by facultative vegetative parthenocarp.

Seedlessness in the Corinth grapes involves two rather distinct conditions, namely; (a) abortion of *all* ovules, of which there are two grades, and (b) parthenocarpy. This situation will readily be understood when one recognizes that the ovule is the unit for seed formation while the ovary is the unit for the fruit. When these grapes are used as pollen parents on hardy seeded grapes of the clones grown in New York it appears that the F_1 bear seeded fruit.

Seeds to the number of about 2,500 have now been obtained for F_2 progenies in which at least some individuals may be expected in whose fruits both parthenocarpy and the abortion of all ovules are combined.

PROGENIES OF SEEDED X STENOSPERMOCARPIC

The most noteworthy result obtained in this breeding is the segregation of seedless along with seeded in the F_1 when the vinifera seedless grapes Sultanina, Sultanina Rose, and Black Monukka are used as pollen parents. In these grapes there is abortion of many ovules. Some ovules are able to function in fertilization but the embryos fail to develop and the seeds are undersized, of irregular shapes and soft and pulpy. Such seeds have been called stenospermic (12) and this type of seedless fruit has been called stenospermocarpic.

Progenies of the Sultanina Seedless Grape:—At the present time between 20 and 30 seedlings which bear grades of stenospermocarpic fruits have appeared in the progenies of Sultanina as a pollen parent with Keuka, Golden Muscat, Ontario and several unnamed seedlings as seed parents. In every case there were sister seedlings which bear seeded fruit. The number of plants in any one of these progenies is rather small. The significant fact is that some seedless plants appeared in the F_1 generation. As many as 85 seedlings in one progeny of Sultanina are being grown and when these have fruited further data will be available. Also progenies for an F_2 generation are being grown.

Progenies of Sultanina Rose:—More than 50 seedlings which bear stenospermocarpic fruits have appeared in progenies of Sultanina Rose. Some of these are the immediate offspring of Stout Seedless (No. 10918) which has the Sultanina Rose as its pollen parent.

The first of this group of cross-pollinations was accomplished in 1921 with a seedling of *Triumph* x *Dutchess* as the seed parent. Thirty seeds were obtained of which only a few germinated. Only two plants lived to bear fruit; one had seeded fruit only and the other No. 10918, named Stout Seedless, (2) bore seedless fruit of the stenospermocarpic type.

A progeny obtained from seedling 8536 (*Goff* x *Ionia*) x *Sultanina Rose* is of special interest. Two hundred seeds were obtained and 68 germinated; and of the 56 plants which fruited, 26 bore fruits that were classed as seedless or near-seedless. Various seeded and seedless individuals of this progeny have been used (a) in selfings and crossings for another generation, (b) in crosses with plants having other seedless ancestry, and (c) in crosses with Sultanina, Sultanina Rose, Black Monukka, Black Russian Seedless, and Black Corinth, but these progenies have not fruited. In view of the segregation of both seedless

and seeded plants in the F_1 , the character of the F_2 obtained from seeded plants will be a matter of special interest.

The Stout Seedless has been used as a pollen parent in combinations from which over 1,000 seeds were obtained, and about 175 plants are being grown. In a progeny of 23 plants of *Golden Muscat* x *Stout Seedless*, 13 have stenospermocarpic fruits, and several of these are classed as promising for culture. Of the progeny *Melton* x *Stout Seedless*, 13 have fruited and eight of these have seedless fruits. In another progeny (8536 x *Stout Seedless*) 11 plants have fruited of which six are seedless or near-seedless. From the cross *Melton* x *Stout Seedless* a total of 178 seeds were obtained, but only 18 germinated and 13 lived to bear fruit of which eight are seedless.

Thus in crosses with several hardy seeded grapes both *Sultanina*, *Rose* and *Stout Seedless* (which has *Sultanina* *Rose* for its pollen parent) have given progenies in which a considerable number of the offspring are seedless or near-seedless. The numbers of plants in these series range from 11 to 56 and the ratio of seeded to seedless approximates 1:1.

These results seem to indicate that in respect to stenospermy, which is the most characteristic feature of this type of seedless fruit, these particular seedless grapes are heterozygous. Possibly the relation may be considered as ss (seeded) x sS (stenospermocarpic) = ss (seeded) and sS (seedless). With this conception stenospermy would be considered dominant to seeded. Evidence as to whether or not the seeded hybrids breed true to the seeded condition will soon be obtained.

There are however, various grades of stenospermy, judging by the relative development of seeds, which indicate that there are further modifying factors. Also there is the inheritance of the abortion of different proportions of the ovules, and the inheritance of parthenocarpy which may be present.

Progenies of Black Monukka:—About 1,500 seeds have been obtained from 18 different combinations with *Black Monukka* as a pollen parent. At the present time few of the seedlings have fruited. A single seedling obtained from 9135 x *Black Monukka* is seedless. Of the cross *Melton* x *Black Monukka* nine plants have fruited of which five are seedless of the parthenocarpic type of fruit. Both the *Black Monukka* and the *Black Russian Seedless*, which is similar in character, have been used in numerous other combinations the progenies of which none have not fruited.

Progenies of Sultana have been obtained with *Golden Muscat*, *Keuka*, *Hercules* and two seedlings and of these crosses a total of 84 plants have fruited. All are seeded. A total of about 250 seeds have been obtained for an F_2 generation. It appears from these results that the stenospermy of the *Sultana* can be considered as dominant to the seeded condition.

Progenies of Concord Seedless:—The clone known as *Concord Seedless*, and also as *Hubbard Seedless*, presumably arose from the *Concord* grape as a bud sport. The fruits are like those of *Concord* in character but are smaller and the largest seeds are usually soft or somewhat brittle and pale green with a conspicuous black area on the dorsal face (12).

The plants of this clone are hardy and the flowers are of the hermaphrodite type, as in the Concord.

The Concord Seedless will occasionally produce seeds which are viable. Five seedlings obtained from selfed seeds produced seeded fruits.

The efforts to utilize the Concord Seedless in breeding to obtain new seedless clones have involved numerous crosses from which the total number of plants obtained in F_2 and in back crosses was, it would seem, sufficient to give the segregation of the seedless genotype unless it involves a genic combination of numerous recessive factors difficult to obtain unless large numbers of progeny are grown. The genetic behavior of the Concord Seedless in crosses with seeded types is hence very different from that of Sultanina, Sultanina Rose, and Black Monukka which also have stenospermocarpic fruits. But Sultana as a pollen parent has not given a seedless F_1 plant.

The results obtained when hardy seeded grapes of the types cultivated in New York are used as seed parents in crosses with pure vinifera seedless (10, 11, 12, and in this report) agree with those obtained when both the seed and pollen parents are vinifera grapes.

In England over 50 years ago five seedless seedlings were obtained in a total of 22 plants from crosses of Esperione and Black Hamburg with pollen of Black Monukka (1, 15). But Ross (6) states that he grew two seedlings from open pollinated seed of Black Monukka and that both bore seeded fruit.

In Italy, Marchi (3) and Alberto Pirovano (4) state that several seedless plants were obtained in F_1 progenies which had Sultanina for the pollen parent and three of these were listed in the nursery catalog of Lugi Pirovano (5).

Breeding for seedless grapes is reported by Snyder (7, 8). He obtained 275 seedlings from various crosses with a seedless variety as the pollen parent. No seedless plant appeared in the progeny of any of the Corinth grapes, Black Corinth, Panariti, or White Corinth. Twenty-nine seedless or practically seedless grapes were obtained in F_1 progenies from crosses in which Sultanina, Sultanina Rose, and Black Monukka were pollen parents.

SUMMARY

In the breeding efforts here reported the stenospermocarpic seedless grapes Sultanina, Sultanina Rose and Black Monukka have been the pollen parents of progenies that are composed of seeded and seedless (stenospermocarpic) individuals. The first F_1 seedless plant thus obtained (Stout Seedless) was used as a pollen parent in crosses with seeded plants and progenies were obtained which consisted of seeded and seedless plants. Eighty-four seedlings which bear stenospermocarpic fruits have now been obtained. About 20 of these are promising for general or commercial culture. The plants are hardy, at least for the average winter at Geneva; the clusters of fruit are well filled and of good or even large size; the fruits are of good or even large size; the fruits are of good flavor and quality, and ripen at Geneva, and the stenospermic seeds which they contain are soft and not noticeable when

the fruits are eaten. Several of the best and most promising of these seedlings are being propagated for trial culture. As would be expected these seedlings vary in vine characters and in the color, flavor, and quality of the fruit.

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Breeding Hardy Muscat Grapes^{1 2}

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THE muscat flavor which is so highly prized by the lover of European grapes was not available to the eastern grape growers until the Golden Muscat, a cross between Muscat Hamburg and Diamond, was introduced in 1927 by the New York State Agricultural Experiment Station. Unfortunately the Golden Muscat requires about the same length of season as the Catawba and therefore will not ripen except in favorable locations. During the past 15 years many seedlings derived from crosses between the Muscat Hamburg, Golden Muscat, and several European muscats have been grown. Only those that have fruited are mentioned in this brief report.

From three selfed seedlings of Muscat Hamburg that were not winter-protected was obtained a small-fruited, reddish-black, seedless muscat. Unfortunately this seedling died before being propagated.

Muscat Hamburg x Collier:—Thirty-four seedlings were set and 28 fruited. Eleven were weak, probably due to winter-injury. Mildew was noted on the foliage of 13. All had intermittent tendrils, European-type of foliage, and upright stamens. The fruit ripened from late to very late and therefore was of no value for New York State. Thirteen seedlings had the oval shape of Muscat Hamburg while 10 were roundish oval, three roundish, and two roundish oblate. Twelve were described as black, eight as reddish black, two as dark red and six as yellow. Eleven of the 28 had a muscat flavor. Nine rated as good, 15 as fair, and four as poor.

Muscat Hamburg x Concord:—Thirty-three seedlings of this cross were planted. Twenty proved to be hardy, two died, and nine showed from slight to serious winter injury. No mildew was noted. All had intermittent tendrils. The stamens were noted on 25 vines and all were upright. In season of ripening two were noted as very late, 19 as late, and five as medium late. In shape of berry, eight were oval and 18 round-oval. Thirteen were described as black, two reddish black, two red and nine yellow. Five were noted as having a slight muscat aroma and none as foxy. Seventeen had a vinous flavor and nine were either subacid or sprightly. Seven ranked as good in quality, 17 as fair, and two as poor. One was held for further test and one for breeding. As usual the Concord did not prove to be of outstanding merit as a parent.

Muscat Hamburg x Croton:—Twelve seedlings were set in the vineyard and nine fruited. All the vines were winter-injured and in most cases the injury was serious. Considering the fact that Croton is predominantly *Vitis vinifera* in type, this injury might be expected. Seven vines showed slight mildew infection. Lobing and pubescence of foliage were predominantly European. The stamens were all upright. Eight

¹The author wishes to acknowledge the help of L. M. Van Alstyne in compiling this data and also of other members in his Division who have aided in making descriptions.

²New York State Agricultural Experiment Station Journal Paper No. 188.

seedlings ripened late and one very late. Eight had oval berries and one roundish oval. In quality four were rated very good, four good and one fair. Four had a muscat aroma and all were vinous flavored. One of the nine was propagated as of possible value for dessert purposes.

Muscat Hamburg x Diamond:—Eleven vines were set and all fruited. Six were vigorous and five were medium vigorous. Only two mildewed. All had intermittent tendrils and upright stamens. Foliage and berries gave evidence of hybridity. Eight had oval berries and three roundish oval. Three produced black, one red and seven yellow fruit. Two had a muscat aroma and all were vinous and sweet. In quality three rated very good and eight as good. One was named Golden Muscat and three others were held for further trial or breeding. As usual, Diamond proved to be a good parent.

Muscat Hamburg x Hubbard and Hubbard x Muscat Hamburg:—Hubbard is an early, attractive black, that usually produces inferior clusters. Fifty-three vines of the first and 23 of the latter cross were set. As not all of the vines have fruited, a complete report cannot be given. Twenty-five vines of the former were rated vigorous, 14 medium vigorous and 14 weak or very weak; while 19 of the latter were vigorous, two medium vigorous, and one weak. The results indicate that the Hubbard when used as a female gave a much higher percentage of vigorous offspring than when used as a male. Sixty-eight had intermittent tendrils and none continuous. Stamens were noted on 41 seedlings and all were upright. The oval shape of Muscat Hamburg appeared in 17 seedlings, the intermediate shape or roundish oval in 17, and round in one. Nineteen gave black fruit, six reddish black, two red, and 12 yellow. In quality, the Muscat Hamburg, used as a female, gave a higher percentage of desirables. However, since a number of seedlings have not fruited, definite conclusions should not be drawn. Sixteen were rated as good to very good, 17 as fair, and two as poor. Muscat aroma was more prevalent in the seedlings that had Muscat Hamburg as the female. Of the 36 seedlings described for flavor, 13 had a muscat aroma. Four of the 36 were retained for further trial.

Muscat Hamburg x Ontario and Ontario x Muscat Hamburg:—Twenty-two of the former and three of the latter were set for fruiting. Ten vines died before fruiting. Seven were rated as hardy, five medium hardy, and the remainder as tender. None mildewed and 19 had intermittent tendrils. Twelve had upright stamens. Type of foliage indicated European foliage. As expected, Ontario introduced earliness. About one-half of the seedlings ripened during midseason, and the remainder late. Five seedlings produced oval berries, six roundish oval, and one roundish. Five were black, one reddish black, two red and four yellow. Seven out of 12 had a muscat aroma. Ten were rated as good to very good and two as fair. Seven of the 12 were held for propagation. Ontario, a Diamond-Winchell cross, has always been a good parent and it maintained its reputation in these crosses.

Muscat Hamburg x Portland:—Twenty vines were set and 14 have fruited. Portland gave little or no more hardness to the seedlings than Ontario. Seventeen had intermittent tendrils and three both intermittent and continuous. Fourteen were noted as having upright

stamens. The fruit of these seedlings on the average ripened slightly ahead of those in the Ontario cross. Eight bore oval-shaped berries, five roundish oval and one round. Two were described as black, three as reddish black, four as dark red and five as yellow. Eight of 13 seedlings had a muscat aroma and none a foxy flavor. In quality six ranked as good, six as fair, and one as poor. Only one was rated as worthy of a further test. As might be expected, the Portland proved to be inferior to Ontario as a parent.

Muscat Hamburg x Ripley:—Seven seedlings were set and six fruited. One was weak and died. Four proved hardy and two suffered from winter-injury. All six were affected slightly by mildew and all had intermittent tendrils and upright stamens. The fruit ripened late and varied from good to very good in quality. In shape, five were oval and one roundish oval. Three were reddish black and three yellow. Muscat flavor was noted in one-half, or three. One was noted as of possible merit for breeding work.

Muscat Hamburg x Triumph:—Nine vines were set and all were weak except two. Four fruited. Slight mildew was noted on all of the seedlings. All produced intermittent tendrils and upright stamens. The fruit ripened late. One was classed as oval and three as round-oval. One had reddish black fruit and three yellow. Muscat flavor was noted in one. Three were noted as fair and one as good. All were discarded.

Muscat Hamburg x Wayne (Mills x Ontario):—Only one seedling was grown. Its fruit was oval, dark red and good in quality. It was held for a second trial.

Station 7576 (Mills x Ontario) x Muscat Hamburg:—(Station 7576 has reflexed stamens and oval, red, late-ripening, good-quality berries). Twenty-nine seedlings were planted but only five have fruited. The five produced upright stamens. Four had oval berries and one roundish oval. One was reddish black, one dark red, two medium red and one light red. One had a muscat aroma and all except one fair were good in quality. None were saved for further trial.

Station 8691 [(Iona x Vergennes) x Jefferson] x Muscat Hamburg:—(Station 8691 has reflexed stamens and roundish oval, red, medium-late, very good quality berries.) Nine vines were set and seven have fruited. Four produced oval berries and three roundish oval. Three were described as reddish black, three as dark red and one as yellow. Six of the seven had a muscat flavor and all were classed as good to very good. None were marked for second test.

Station 10410 (Muscat Hamburg x Collier) Selfed:—(Station 10410 has upright stamens and roundish oval, black, late and good quality fruit.) Thirty-two were planted and all died except seven and these seven were weak. These selfs, like most other selfs, lacked sufficient vigor to carry on.

Station 10410 (Muscat Hamburg x Collier) x Seneca:—Eighty-three vines of this cross were set and 10 died. Sixty-three were classed as of good vigor, five as medium, and four as weak. All the seedlings produced intermittent tendrils and European-like foliage. Thirty-six produced upright stamens. Nearly all the seedlings ripened in mid-season, that is, midway between the parents. Eleven had oval berries,

13 roundish oval, four roundish, and two slightly oblate. In color 11 were black, seven purplish black, 12 dark red and one red. No yellows or muscat-flavored grapes appeared in the 33 noted. Twelve were judged as good in quality, 17 as fair and one as poor. None were marked for propagation.

Station 10420 (Muscat Hamburg x Ripley) x Khalili:—(Station 10420 has upright stamens and oval, yellow, late, good quality fruit.) Thirty-three vines were set, five died and five fruited. Twenty-five were described as vigorous, one medium vigorous and one weak. Winter injury varied from none to complete killing. All vines recorded had intermittent tendrils and a vinifera-type leaf. Four were noted as having upright stamens. Only five fruited and two were marked for further test. Four had oval and one roundish oval berries. All were yellow and good in quality. No muscat aroma was noted.

Station 10436 (Bakator x Brocton) x Muscat Hamburg:—(Station 10436 has reflexed stamens, and oval, yellow, late and good quality fruit.) Fifty-seven vines of this cross were set and 10 died before fruiting. Forty-one were rated as vigorous, five as fairly vigorous, and one as weak. Eighteen produced upright stamens and one reflexed. Twenty-one have fruited; the season usually being late. The oval type of berry also appeared as in the other crosses; nine being oval and 11 roundish oval. In color, two were black, six were red and 13 were yellow. Eleven of the 21 had a muscat aroma. Fifteen rated as good, five as fair and one as poor. Three were propagated for further trial.

Station 10526 (Muscat Hamburg x Croton) x Khalili:—(Station 10526 has upright stamens and oval, black, late, good quality fruit.) Sixty-four vines of this cross were planted and 10 died. As in the previous cross, winter-injury varied from 0 to 100 per cent. Most all vines, including the partially injured, made a vigorous growth. All had intermittent tendrils and a European type of foliage. Twelve had upright stamens and eight reflexed. Twenty-eight fruited and their season varied from very early to late. Twenty had oval-shaped berries, six roundish oval, and two roundish. Two were black, four reddish black, five dark red, three red, and 14 yellow. Twenty-three were rated as good to very good and two as fair. Six had a Khalili flavor but none a muscat aroma. Six of the 28 were held for further trial and breeding work.

Station 10526 (Muscat Hamburg x Croton) x Melton:—Fifty-seven vines of this cross were set and two died. Most of the vines had little winter injury and with one exception made a vigorous growth. The tendrils were all intermittent and the foliage showed vinifera characteristics. Thirty-two had upright stamens and 15 reflexed. In season the seedlings ran from medium to late, the earliest being 1 month later than the earliest of the previous cross. Thirty-eight were oval, or occasionally slightly ovate, 12 roundish oval, and two roundish. In color six were black, eight reddish black, 10 dark red, and 28 yellow (two had a reddish tinge). Five had a muscat aroma. Forty were good to very good in quality and 12 were fair or better. Three were marked for further propagation.

Station 10774 [(Chasselas Besson x Diana) x Melton] x Muscat

Hamburg:—(Station 10774 has upright stamens and oval, yellow, late, good quality fruit.) Twenty-four seedlings were set and 10 have fruited. Over one-half of the vines had excellent vigor and the others varied from fair to weak. Ten had upright stamens and 21 intermittent tendrils. Four had oval berries and six roundish oval. Six inherited a muscat aroma and eight were judged good and two fair. None have been propagated for second trial.

Station 10782 [10144 (Mills x Triumph) x Diamond] x Muscat Hamburg:—(Station 10782 has upright stamens and roundish oval, yellow, late and good quality fruit.) Six of the 17 set have fruited. Nine were rated as of good vigor, three as fair and five as weak. All had intermittent tendrils and eight upright stamens. One produced oval berries, four roundish-oval, and one roundish to slightly oblate. One had black fruit, two reddish black, one dark red, and two yellow. A muscat flavor was noted in one of the six. Five were noted as fair in quality and one as poor. None were held for further trial.

The results from these crosses prove that the muscat flavor is transmitted to the first generation. Although data are not complete for the 17 crosses between varieties and seedlings and Muscat Hamburg, what are available have been assembled. Of the 197 seedlings that have fruited, 80 have a muscat flavor. Twenty-four of these seedlings, 12 with a muscat flavor, have been propagated for further trial. In fact one of them, namely Golden Muscat, has been out for trial since 1927. The selfed seedlings of Muscat Hamburg and Muscat Hamburg x Collier were all weak. Four other seedlings derived from previous Muscat Hamburg crosses when crossed with Seneca, Khalili, and Melton gave 118 seedlings, five of which had a muscat flavor. One of these five and two others with a vinous flavor were marked for further trial. The total muscat-flavored seedlings is thus 85. Thirteen of the 85 are being propagated for an extensive test. Many more muscat-flavored grapes should soon be available for a number of seedlings derived from muscat crosses are growing either in the vineyard or nursery. Judging from the performance of these seedlings it is evident that before long several hardy muscats will be available to the eastern growers.

Hastening the Production of Fruit in Grape Hybridizing Work

By ELMER SNYDER and F. N. HARMON, *U. S. Department
of Agriculture, Fresno, Calif.*

A METHOD of procedure to hasten the fruiting of grape seedlings has been followed at the United States Experiment Vineyard, Fresno, California, during the past 2 years. Various methods of budding and subsequent care were tried. The use of the ordinary "T" bud with some modified treatments has resulted in the production of ripe fruit 18 months after the grape seeds were planted in greenhouse flats. This quick fruiting of seedlings has been obtained in the following manner.

Grape seeds from controlled crosses have been planted in flats and started under greenhouse conditions about February 1. The seedlings were transplanted to gallon cans after three or four true leaves were formed. During May and early June, these seedlings have attained a length of from 12 to 16 inches, as indicated in Fig. 1-A. At this time, three to four buds from the basal part of the seedling shoot suitable for "T" budding can be obtained and are "T" budded into vigorous-growing shoots of rootstocks or bearing vines which have been growing in vineyard form. After the buds are inserted, they are securely wrapped with rubber grafting-tape. The budded shoots then are pinched off at the tip to check terminal growth. A week to 10 days later, the shoot is cut back to the bud, leaving some of the original leaves on the shoot to shade the bud. In practice, three and four buds are inserted in each shoot. If all buds start as shown in Fig. 1-B, the weaker ones are pinched back and the strongest allowed to grow. During the past season, 1,586 buds were inserted and 78.9 per cent of them grew. Shoots developing from these buds trained on wires have grown 6 to 12 feet by the end of the growing season. At pruning time, a cane 3 to 4 feet long can be left for the next season's fruiting wood, as shown in Fig. 1-C. At the Fresno station, ripe fruit has been picked in August, 18 months from the time the seeds were planted in the greenhouse flats. Fig. 1-D shows a cluster produced in this manner from selfed seeds of the variety Agadia.

There are some precautions necessary to obtain growth from a good percentage of the buds. Where excessive temperatures are encountered, it has been found necessary to provide some form of shade. Brush pruned from the vines at the time of budding has been placed across the trellis over the buds. Muslin shade cloth has also been stretched along the rows over the bud to afford partial shade. The shoots should be cut back at the proper time to force the small seedling buds into growth. Constant upright training has been found to promote rapid growth. The rubber grafting-tape must be cut if it does not break of its own accord.

A quick fruit-reading can be obtained by this method, gaining at least one year if not two over ordinary methods of propagating grape

seedlings. While the final commercial merits of a seedling can not be told by this method, many qualities such as color, shape, size, and flavor of fruit can be determined.

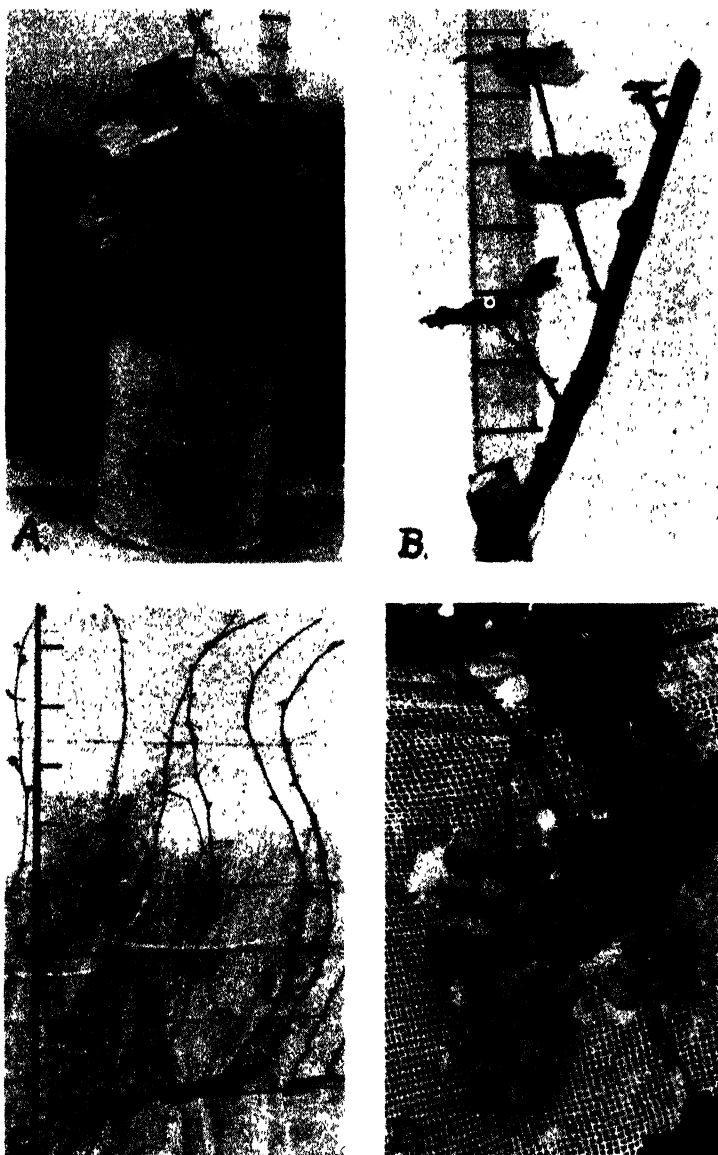


FIG. 1. A growth and fruiting of seedlings after "T"-budding on vigorous vines.

A Subirrigation Method of Supplying Nutrient Solutions to Plants Growing Under Commercial and Experimental Conditions

By ROBERT B. WITHROW and J. P. BIEBEL, *Purdue University
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ABSTRACT

This material will be published in full in the *Journal of Agricultural Research*.

A SUBIRRIGATION method of supplying nutrient solutions to plants growing in sand culture which lends itself to large scale production was described. It consists in principle of pumping nutrients from a submerged reservoir into the bottom of a shallow bed of fine gravel or cinders with a centrifugal pump. The pump is controlled by an electric time switch which stops the operation when the bench is flooded. The solution then flows back into the tank through the pump by gravity.

Modifications of the method are discussed for use in experimental set-ups on a small scale.

The advantages of the system are (a) frequent and complete flushing of the roots with air and nutrient solution, (b) economy of nutrients since the solution drains back into the tank again, and (c) completely automatic operation over long periods of time.

A method was presented for modifying the conventional physiological nutrient solutions for use with commercial fertilizer salts.

Interrelation of Size of Seed Piece and Rate of Application of Fertilizer in the Production of Potatoes in Alabama

By L. M. WARE, *Agricultural Experiment Station, Auburn, Ala.*

ABSTRACT

(This paper will be published in full in the American Potato Journal.)

IN an experiment companion to the one reported above yields per acre, cost per acre for materials, cost of potatoes per bushel, and returns per acre above the cost of materials are given for three rates of application of fertilizer with each of four sizes of seed pieces. The rates of application of fertilizer consisted of 1,000, 1,500, and 2,000 pounds per acre. The seed pieces weighed $\frac{1}{2}$ ounce, $\frac{3}{4}$ ounce, 1 ounce, and $1\frac{1}{2}$ ounces. All seed pieces were spaced 16 inches. The highest yield of No. 1 potatoes at each rate of fertilizer application was obtained with $1\frac{1}{2}$ ounce pieces; however, at the 1,000-pound-per-acre rate of fertilizer application only a very small increase in yield was obtained by increasing the size of seed from 1 ounce to $1\frac{1}{2}$ ounces. The highest returns per acre above the cost of materials were obtained from the use of 1,500 pounds per acre of fertilizer and $1\frac{1}{2}$ ounce pieces. The cost of potatoes per bushel was largely determined by a proper balance between the quantity of fertilizer applied and the size of seed piece used.

Interrelation of Spacing of Seed Piece and Rate of Application of Fertilizer in the Production of Potatoes in Alabama

By L. M. WARE, *Agricultural Experiment Station, Auburn, Ala.*

ABSTRACT

(This paper will be published in full in the American Potato Journal.)

THIS is one of a series of three related experiments designed to study the economics of production of Irish potatoes in Alabama as affected by the interrelation of three factors: rate of application of fertilizer, size of seed piece, and spacing of seed piece. Yield per acre, cost per acre for material, cost of potatoes per bushel and returns per acre above the cost of materials are given for three rates of application of fertilizer at each of four spacings of seed piece. The rates consisted of 1,000, 1,500, and 2,000 pounds per acre. The spacings were 20, 16, 12, and 8 inches. All seed pieces weighed 1 ounce. The highest yield of No. 1 potatoes at the 1,000, and at the 1,500-pound-per-acre rates of fertilizer application was produced with a 12 inch spacing; at the 2,000-pound-per-acre rate the highest yield was obtained with an 8 inch spacing. The largest returns after the cost of materials was deducted were obtained from the use of 2,000 pounds per acre of fertilizer and a 12 inch spacing. The data showed definitely the need of a balance between the quantity of fertilizer applied and the quantity of seed used.

Germination of Seeds of the Potato as Affected by Temperature

By H. L. STIER and H. B. CORDNER, *University of Maryland, College Park, Md.*

THE practice of propagating the potato plant by means of its tubers has resulted in little attention or thought being given to the seeds as a means of plant production. However, potato improvement by modern breeding methods has become increasingly important and the production of potato seedlings has become a relatively common practice. Hence, a knowledge of the germination requirements of potato seeds has become exceedingly valuable.

Although considerable information is available concerning the relationship of temperature to the germination of the seeds of many crop plants, very little is available relative to the germination of seeds of the potato. The investigations of Kotowski (3) and of Harrington (2) have shown that seeds of certain species germinate throughout a rather wide range of temperatures while in others germination is limited to a very narrow temperature range. The reader is referred to Edwards (1) for a more comprehensive review of the relationship of temperature to the germination of seeds.

MATERIALS AND METHODS

All seeds were secured from seed balls which developed from natural pollination and matured on plants in the field, and at the time the experiment was begun had been stored 1 year at room temperature. Seeds of the variety Katahdin were used in 1935 and those from a seedling variety (U. S. D. A. 0160) were used in 1936.

All seeds were germinated on five sheets of No. 1 filter paper placed in Petri dishes and kept moist with tap water. Two hundred and fifty seeds, divided into five lots of 50 seeds each, were placed at each temperature. The coefficients of velocity of germination and all other values presented are averages of the five lots. The differences necessary for significance were calculated from the standard error secured from an analysis of variance, and the coefficients of velocity of germination were calculated according to the method proposed by Kotowski (3).

In 1935 the seeds were germinated in three different rooms which provided the mean temperatures of 17, 20 and 28 degrees C. Thermographic records were kept at each location. In 1936 temperatures ranging from 0 to 35 degrees C were used, each temperature being controlled thermostatically except at 25 degrees. The deviations from the mean temperatures are indicated in Table I.

RESULTS AND DISCUSSION

No germination occurred at 0, 5, and 35 degrees C and at 30 degrees only 1 per cent of the seeds germinated after 45 days. Removal of the seeds from these temperatures to 20 degrees C resulted in prompt germination. The data secured at the range of temperatures effective in producing germination are presented in Table I.

TABLE I—THE EFFECT OF TEMPERATURE ON THE RATE AND FINAL PER CENT OF GERMINATION OF 1 YEAR OLD SEED

	Temperature (Degrees C)							Significant Difference
	17±3.5	20±2	28±2	10±1	15±1	20±.5	25±2.5	
Year	1935			1936				
First seedling—days	4	4	4	9	3	3	3	—
Last seedling—days	18	16	38	21	15	12	13	—
75 per cent germination—days . . .	5.8	4.9	27.9	13.1	5.6	4.3	7.9	.6
Coefficient of velocity	16.2	18.0	5.5	7.7	17.5	23.7	12.9	5.1
Per cent of germination	89.1	89.3	89.4	65.7	90.4	90.0	91.6	6.8

It is evident from the data presented that the *temperatures from 15 to 28 degrees C were effective in promoting germination, but at 10 degrees there was a marked and significant reduction in the per cent germination.*

The rate of germination showed a definite trend in relation to temperature. The germination rate was slow at 10 degrees, increased with temperature to the maximum at 20 degrees above which it progressively decreased to a minimum at a temperature of 28 degrees. This trend is evident from the three expressions of germination rate, *i.e.*, days to the last seedling, days to 75 per cent germination and the coefficient of velocity of germination.

Of the temperatures used 20 degrees C proved the most favorable for germination. However, it would not be safe to conclude that this is the optimum temperature, in fact the data suggest that the optimum is probably slightly below this temperature, since the decline in rate of germination was much less between 20 and 15 degrees than it was between 20 and 25. Further studies are planned to test the validity of this assumption.

It is interesting to note that as the result of recent studies the germination response of "new" seeds at the different temperatures is slightly different from that of year old seed. No germination occurred at 10 degrees with new seed while the most rapid germination resulted at 20 degrees followed closely by 25 and slowest at 15 degrees. The germinative response of new seed will be presented in detail in a later paper.

CONCLUSIONS

No germination of year old seed occurred at 0, 5, and 35 degrees C and at 30 degrees only 1 per cent germinated after 45 days. At temperatures between 15 and 25 degrees C the per cent germination was uniformly high (89 to 91 per cent) while at 10 degrees the per cent germination was significantly lower. The rate of germination was most rapid at 20 degrees C.

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The Significance of Pre-emergence Soil Moisture to Yield of Potatoes on Dry Land in the Western High Plains Area

By H. O. WERNER, *University of Nebraska, Lincoln, Neb.*

ABSTRACT

This paper will be published in the *American Potato Journal*.

IN the high plains area in western Nebraska precipitation occurring prior to planting time or at least prior to emergence of main season plantings of potatoes has been a more significant factor in the production of satisfactory yields than rainfall. The potato crops have practically been failures when planted after small grain because of the serious depletion of soil moisture as deep as the 5th foot. Potato yields after corn have been fairly good as this crop removed very little moisture below the third foot. Best potato yields have been obtained following summer fallow. During summers of little rainfall potatoes removed practically all available moisture from the upper 5 feet of soil.

Delayed Germination in Seeds of the Potato

By H. L. STIER, *University of Maryland, College Park, Md.*

IN the breeding of potatoes (*Solanum tuberosum*) it is frequently desirable to plant recently harvested seed (from the late crop) in the greenhouse to secure tubers for spring planting. This newly harvested seed normally germinates very slowly and irregularly, requiring from 100 to 140 days to complete germination. Obviously such behavior hinders the work of the potato breeder. If the number of seedlings which emerge during the first 20 or 30 days after planting are used, only a small proportion of the potential population is obtained. To secure seedlings from all viable seeds requires much additional labor and time. Furthermore the plants vary so widely in the time of attaining maturity that many of them produce tubers too late for spring planting.

Although the importance of the problem is recognized it is of comparatively recent origin and there is a surprising dearth of available information. Stevenson and Milstead (3) state that new seeds do not germinate as well as year old seeds. Stcherbacheva (2) points out that the germination of the seed is influenced by the length and condition of storage and that the irregularity observed in the germination of new seed slowed up the breeding program since it made selection very difficult or impossible during the first two years. Bukasov (1) makes no statement regarding germination of new seed but outlines investigations now in progress to determine the conditions required for germination of the seed from various potato species.

This report includes part of the results secured from an investigation undertaken to determine the factor or factors causing the slow germination of potato seed. From this knowledge it is hoped that a method can be developed whereby new seed can be made to germinate more rapidly and uniformly.

MATERIALS AND METHODS

The seeds were secured from plants which had set seed balls in the field as the result of natural pollination. The period from the time of harvesting the seed balls to planting the seeds varied with different lots and is designated in Table I as age of the seed.

TABLE I—RELATION OF AGE OF POTATO SEED TO GERMINATION RATE

Age of Seed	Katahdin		Seedling* 45075		Green Moun- tain	Seedling* 336-339	
	30 Days	365 Days	30 Days	365 Days	365 Days	145 Days	200 Days
First seedling (days)	31	5	16	5	5	10	5
Last seedling (days)	131	28	134	20	35	63	16
75 per cent germination (days)	94.9	11.1	94.3	10.4	10.2	34.0	10.0
Coefficient of velocity of germination	1.1	8.4	1.2	9.9	8.1	4.0	11.0
Per cent germination	72.9	71.0	61.3	62.2	81.7	92.0	91.5

*U.S.D.A. Seedling varieties.

The seeds were germinated in soil and in Petri dish germinators. When soil was used, lots of 300 and 500 seeds were planted approximately $\frac{1}{8}$ inch deep in rows across the width of flats. The flats were kept in a greenhouse where the temperature varied between 20 and 26 degrees C. The seedlings were counted and removed a short time after they emerged. Petri dish germinators were prepared as described previously (4) and two to four replicates of 50 seeds each were used. Seeds with the radicle protruding $\frac{1}{16}$ inch or more were counted as germinated and removed. During the course of the 2 years work a total of approximately 30,000 seeds were used in the various tests.

RESULTS AND DISCUSSIONS

In Table I are presented data illustrating the condition described as delayed germination. It required 130 days or more for all the seeds to germinate when planted 30 days after harvesting while the same lot of seed one year later completed germination within 20 to 35 days. The coefficients of velocity at the end of a year were about eight times as large as those obtained from the seed when planted 30 days after harvesting. One hundred forty-five days after harvesting, seed of variety 336-339 germinated much faster than 30 day old seed of the other varieties but was still much slower than year old seed. The same seed 200 days after harvesting germinated at a rate equal to that of the year old seed. The apparently higher per cent germination and rate of germination (at 200 days) in this variety is attributed to the fact that the seeds were germinated in Petri dishes while those of the other varieties were germinated in soil.

A number of treatments have been used with new seed in an effort to shorten the period of germination. These treatments are conveniently classed into two groups: (a) those designed to hasten germination by chemical stimulation or by after ripening, and (b) those designed to eliminate the seed coat or other tissues exterior to the embryo as factors in delaying germination. These studies are still in progress and are too extensive to describe in detail in this report.

1. Seeds stored at 0 degrees C 50 days in seed balls, germinated significantly slower than seeds from berries stored an equal time at room temperature.

2. Soaking seeds in 6 per cent aqueous solution of ethylene chlorhydrin for 12 hours had no effect upon rate of germination.

3. Soaking seeds in 5, 10, 25 and 50 per cent solutions of ethyl alcohol for 1 hour proved to be ineffective.

4. Recent tests indicated that treating seeds with concentrated sulfuric acid for 1 minute may be effective in speeding up germination. When soaked in acid concentrations of 2, 5, 10 and 25 per cent for 45 minutes no effect was noted.

5. In many cases rupturing or removing the seed coat effected germination when untreated.

6. Slitting the seed coat and the endosperm through to the embryo at the hilum end of the seed caused the emergence of the radicle and growth of the embryo.

7. "Sanding" off the seed coat on the flattened sides of the seed caused a lateral emergence of the cotyledons and hypocotyl with the radicle remaining in the seed.

CONCLUSIONS

Seeds of the potato exhibit delayed germination until 4 to 5 months after they have been harvested.

Results of certain special seed treatments indicate that the embryo is not in a state of rest but that the delayed germination is caused by some tissue or agency exterior to the embryo.

ACKNOWLEDGEMENT

Grateful acknowledgement is made to Dr. H. B. Corder of the University of Maryland for helpful assistance and advice rendered during the course of the investigation; to Dr. F. J. Stevenson of the U. S. Department of Agriculture for suggesting the study and to Dr. C. F. Clark of the U. S. Department of Agriculture for supplying part of the seeds used.

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The Effect of the Sungreening of Potato Seed Tubers on Weight Losses in Storage and on Subsequent Field Performance

By K. C. WESTOVER, *West Virginia University, Morgantown, W. Va.*

ABSTRACT

The complete paper will be published in the *American Potato Journal*.

THE studies reported in this paper were made to determine the effect of sun-greening of the potato seed tuber in the fall, when sprouts are not normally formed, on weight losses during the sun-greening and storage periods and on subsequent plant growth and yields under field conditions. The control tuber samples were subjected to relatively similar conditions except that they were held in darkness. The White Rural variety of potato was used.

Determination of tuber weight losses during the greening and subsequent storage period was made for two seasons. Weight records were taken immediately before and after the greening period and again at the end of the storage period. The percentage loss in weight was computed for each tuber for the different periods and the means of the losses from the tubers of each treatment were compared. These experiments showed that under conditions conducive to rapid greening, the treatment had no marked effect on loss of weight from tubers during the greening or subsequent storage periods, but under conditions favoring slow chlorophyll development, the greened tubers lost more weight.

The same tuber samples upon which records of losses of tuber weight in storage had been taken were planted the following seasons to determine the effect of the treatment on plant growth and yields. Adjacent duplicate plantings were made with the longitudinal halves of the same tubers. The distribution of the tuber sets of the treatments was systematic. Wide spacings were used and observation and measurements were made on the individual plants. Data were taken on the time of plant emergence, earliness of development of flower buds, the number of stalks per hill, the height and span of the plant, and the yields and number of tubers per hill. Little consistent evidence was obtained to indicate that the sun-greening treatment had any effect on the time of plant emergence or its later development.

There was no evidence from these studies that the sun-greening of potato seed tubers before storage was of practical value.

The Influence of Planting Date on the Yield, Quality and Development of the Russet Burbank Potato

(A Preliminary Report)

By C. H. METZGER, *Colorado State College, Fort Collins, Colo.*

IT is well known by those who have tried to grow the Russet Burbank that it is one of the most difficult varieties to grow to perfection. An uneven supply of moisture after tuber set, a period of hot weather, or any other factor which may check growth and then induce it again, will cause the development of knobs and reduce practically the entire crop to No. 2's and culls. It also requires a very fertile soil and abundant water for maximum yields. Because of its peculiarities, it is adapted to only one of the four main potato districts in Colorado, and even here the percentage of U. S. No. 1 is lower than other varieties. The test was located at the Mountain Substation, which is on the eastern edge of the Russet Burbank district, at an altitude of 7,600 feet. Satisfactory quality has been difficult to obtain in the Eagle Valley-Carbondale District, but it remains the standard variety because of its scab resistance and an established market.

Observations in the district seemed to indicate that better results were obtained by planting somewhat later than is the usual practice. Since the Russet Burbank is not as late a variety as the Rural or Peachblow, some latitude might be allowed in planting date without sacrificing too much in maturity. It is the object of this experiment to determine the most satisfactory planting date for the production of the highest yield of the best commercial quality and to study the development of the plant as influenced by different planting dates.

METHODS

Planting was begun May 4, which is as early as ground can ordinarily be worked in this location and continued at weekly intervals until June 15. The plot was alfalfa sod land which had been fall plowed. The month of May was the driest since the establishment of the station in 1924, but precipitation for June, July, and August was above normal, and there was an abundance of irrigation water. The plots were irrigated four times. The potatoes were planted in 3-row plots, rows 3 feet apart, with 15 inches between hills. The center row of each plot was divided into six, 60-foot plots, just previous to harvest. The data were analyzed by Students' method for paired plots, calculating the value of "t" and determining P from Fisher's (1) "t" table.

INFLUENCE ON YIELD

The data on yields this year show that it is possible to plant this variety too early as well as as too late for best results.

The May 4 planting produced 302 hundred weight per acre, which was significantly higher than May 25 and later, but was lower than May 11 and May 18, but not significantly.

The May 11 yield was 310 hundred weight per acre, which was also significantly higher than May 25 and later, but significantly lower than May 18. It was a little higher than May 4, but not significantly so.

The May 18 yield was 328 hundred weight per acre, which is also significantly higher than May 25 and later, and also May 11; but in spite of the higher yield than May 4, the difference is not significant.

TABLE I—YIELD IN HUNDRED WEIGHT PER ACRE AND PERCENTAGE OF TOTAL YIELD OF NO. 1, KNOBS AND CULLS FROM THE VARIOUS DATES OF PLANTING, 1936

Planting Date	No. 1 (Cwt. per Acre)	Per Cent No. 1	Knobs (Cwt. per Acre)	Per Cent Knobs	Culls* (Cwt. per Acre)	Per Cent Culls	Total Yield
May 4	229.0	75.60	35.02	11.56	38.87	12.83	302.0
11	217.2	69.87	47.64	15.32	46.05	14.81	310.0
18	273.0	82.99	19.08	4.46	41.28	12.55	328.0
25	148.1	69.57	14.61	6.86	50.18	23.56	212.0
June 1	145.4	68.60	19.01	8.97	47.55	22.43	211.0
8	106.5	58.23	13.92	7.61	62.51	34.16	182.0
15	70.7	46.53	7.07	9.41	66.97	44.06	151.0

*Includes tubers through 1 $\frac{3}{8}$ -inch screen and those badly off shape.

The May 25 yield of 212 hundred weight per acre was significantly higher than June 15, but significantly lower than May 4, May 11, and May 18.

The June 1 yield of 211 hundred weight per acre is significantly higher than June 15, and significantly lower than May 4, May 11, and May 18.

The June 8 yield was 182 hundred weight per acre, which is significantly lower than May 4, May 11, and May 18.

The June 15 yield was 151 hundred weight per acre, which is significantly lower than all other dates except June 8.

From the standpoint of yield, May 18 proved to be the best planting date in 1936.

INFLUENCE ON GRADE

With the Russet Burbank variety the yield of No. 1 tubers is of much more importance than the total yield. The tubers from each date of planting were graded over 1 $\frac{7}{8}$ -inch screen, and the yield and percentage of each classification are given in Table I.

The May 18 planting not only gave the highest total yield but also gave the highest yield of No. 1 stock exceeding May 4 by 44 sacks per acre. This planting date also produced the lowest percentage of knobs and culls. The highest percentage of knobs was produced by the May 11 planting. The higher percentages of culls, of course, occurred in the later plantings because of the increase in the number of small tubers.

INFLUENCE ON STARCH AND DRY MATTER

Samples of tubers from each planting date taken after harvest on October 10 were analyzed by the Chemistry Section. The starch and dry matter percentages are as follows:

Date	Starch (Per Cent)	Dry Matter (Air Dry Basis)
May 4	18.419	25.34
May 11	18.720	24.88
May 18	17.515	24.88
May 25	17.628	24.33
June 1	16.611	23.71
June 8	17.289	23.59
June 15	15.820	23.51

TABLE II—RATIO OF TUBERS TO VINES (1936)

Harvest Date	May 4			May 11			May 18		
	Tubers	Vines	Ratio	Tubers	Vines	Ratio	Tubers	Vines	Ratio
July 13.....	3.5	18.12	0.193	1.5	19.25	0.078	4.25	24.5	0.173
July 20.....	10.25	29.87	0.343	5.12	28.75	0.178	6.00	26.25	0.229
July 27.....	14.75	30.00	0.492	10.00	31.00	0.323	11.25	39.50	0.285
Aug. 3.....	26.75	41.50	0.645	20.12	51.00	0.395	24.12	38.00	0.635
Aug. 10.....	35.50	63.00	0.563	23.37	57.00	0.410	42.00	63.00	0.667
Aug. 17.....	50.00	50.00	1.000	39.50	65.00	0.608	54.00	61.50	0.878
Aug. 24.....	79.00	71.50	1.105	59.00	74.50	0.792	87.00	63.50	1.370
Aug. 31.....	101.00	90.50	1.116	70.00	64.00	1.094	93.00	62.00	1.500
Sept. 7.....	112.00	63.00	1.778	96.00	69.00	1.391	100.00	63.00	1.590
Sept. 14.....	102.00	54.00	1.889	108.00	66.00	1.636	113.00	50.00	2.260
Sept. 21.....	105.00	41.00	2.561	97.00	47.00	2.064	104.00	26.00	4.000
Sept. 28.....	94.00	23.50	4.000	104.00	25.00	4.160			

Harvest Date	June 1			June 8			June 15		
	Tubers	Vines	Ratio	Tubers	Vines	Ratio	Tubers	Vines	Ratio
July 13.....	—	—	—	—	—	—	—	—	—
July 20.....	—	—	—	—	—	—	—	—	—
July 27.....	1.50	13.25	0.113	—	—	—	—	—	—
Aug. 3.....	3.00	16.25	0.185	—	—	—	—	—	—
Aug. 10.....	7.19	19.50	0.369	1.13	18.63	0.061	—	—	—
Aug. 17.....	19.50	31.00	0.629	6.50	26.19	0.248	1.00	23.69	0.042
Aug. 24.....	30.50	36.00	0.972	29.00	39.00	0.718	6.50	30.50	0.213
Aug. 31.....	42.00	41.00	1.024	39.50	48.50	0.808	14.00	38.50	0.364
Sept. 7.....	55.00	39.00	1.410	51.00	55.00	0.927	19.50	37.50	0.520
Sept. 14.....	65.00	37.00	1.757	59.00	45.00	1.311	40.00	36.00	1.111
Sept. 21.....	82.00	44.00	1.864	88.00	52.00	1.692	54.00	37.00	1.459
Sept. 28.....	96.00	21.00	4.571	78.00	38.00	2.053	61.00	35.00	1.743
				74.00	22.00	3.364	54.00	28.00	1.929

The starch content of the tubers did not decline regularly with the later planting dates but did show a tendency in that direction. The dry matter percentages, however, declined with later planting.

INFLUENCE ON SHAPE AND APPEARANCE OF TUBERS

One hundred tubers, weighing between 7½ and 9 ounces were selected at random from each planting date, measured for length, width, and thickness; and the length-width, and width-thickness ratios calculated. These are presented in Table II.

In general appearance the ranking was from the earliest to the latest, except for potatoes planted May 25, which were last, mainly because of poor shape.

In maturity there was little difference between potatoes planted May 4 and May 11. Those planted May 18 showed more skin loss than those from the earlier plantings. There was again little difference between potatoes planted May 25 and June 1, while those planted June 8 showed more skin loss, and those planted June 15 almost a 50 per cent loss of skin.

Potatoes from the first three planting dates show more prominent netting than the later dates, and there is a slight decrease from May 25 to June 15.

There was also a distinct change in color in tubers from these planting dates. The May 4 planting had a distinct gray color with a pale, golden under color. The May 11 planting was much the same but slightly darker. By May 18, the golden color had darkened to a brown tinge, and the gray almost disappeared. May 25 the brown was still darker, and more dirt adhered to the tubers. The June 1 planting was much the same as May 25. The June 8 planting was quite brown, a little deeper than the previous two dates, and June 15 again showed more of a yellowish cast, probably due mainly to lighter netting which was more of a flaking than netting.

RATE OF TUBER DEVELOPMENT

Thirty hills were dug from each date of planting at weekly intervals beginning July 13 on the earlier planting dates, but not starting until August 10 on the planting of July 15. The weight of tubers from each digging date is given in Table II. A killing frost occurred on September 27; and contrary to popular belief, the tuber weights decreased after this time. The tubers reached their maximum weight and made their greatest increase in weight as follows:

Planted	Maximum Weight	Maximum Increase
May 4	September 7	August 17 to August 24
May 11	September 14	August 31 to September 7
May 18	September 21	August 24 to August 31
May 25	September 28	September 7 to September 14
June 1	September 28	September 7 to September 14
June 8	September 14	September 7 to September 14
June 15	September 21	August 31 to September 7

The rate of tuber development in the later plantings was much faster than from the earlier plantings as would be expected from the fact that

the shorter days and lower temperatures would favor tuberization regardless of the date of planting. The tuber development at weekly intervals for 11 to 21 weeks after planting is shown in Fig. 1.

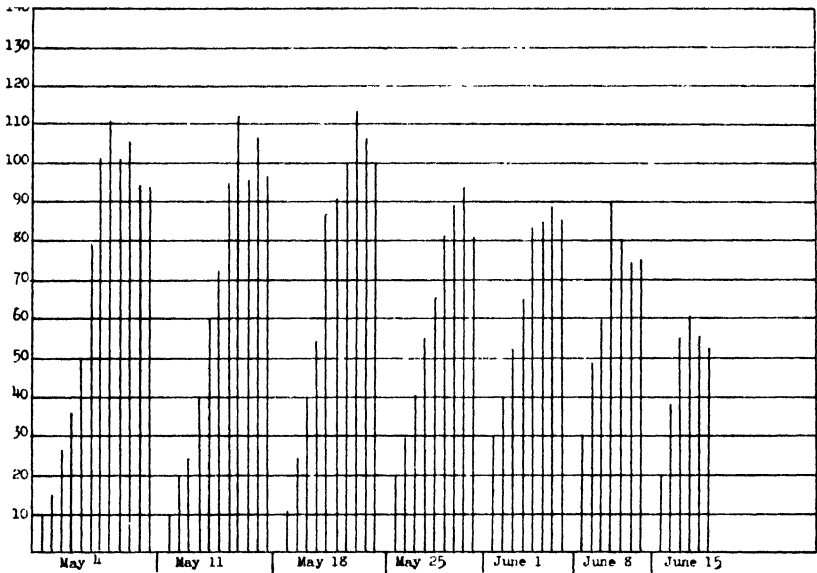


FIG. 1. Tuber weights from dates of planting at weekly intervals starting 10 weeks after planting. Weights in pounds per 30 hills.

The June 8 planting produced the highest yield of tubers for a given interval after planting until after the fifteenth week. The June 1 planting was second until the sixteenth week. The June 15 planting was a close third until the fourteenth week. The May 25 planting was fourth until the fourteenth week, when it was exceeded by the May 18 planting, but it remained ahead of the May 4, and May 11 plantings until after the sixteenth week. The May 4 and May 11 plantings are very close until the sixteenth week, when May 4 forges ahead of May 11.

INFLUENCE ON TUBER SET

The average number of tubers per hill for 90 hills from each planting date was as follows: May 4, 9.54; May 11, 10.66; May 18, 10.64; May 25, 10.13; June 1, 11.08; June 8, 9.77, and June 15, 14.56. Another interesting relationship was the difference between the number of tubers set and the number harvested. The average number of tubers per hill from 120 hills was determined as soon after tuber set as possible for each date of planting. The difference between the number set and number harvested decreases with the later planting dates. For the May 4 planting, the decrease was 8.8 tubers; for May 11, 6.11 tubers; for the May 18 planting, 5.07 tubers; for May 25, 4.48 tubers; for June 1, 3.67 tubers; for June 8, 4.05 tubers, and for June 15, 3.96 tubers.

TABLE III—AVERAGE TUBER MEASUREMENTS IN CENTIMETERS, RATIOS, AND SHAPE INDEX FROM DIFFERENT DATES OF PLANTING, 1936

Planting Date	L	W	T	L/W	W/T	Shape Index*	Average Weight of Tubers (Ounces)
May 4 . . .	12.51	6.14	4.93	2.04	1.25	2.260	8.61
May 11. . .	12.17	6.11	4.83	1.99	1.26	2.224	8.33
May 18 . .	12.27	5.93	4.86	2.07	1.22	2.274	8.60
May 25. . .	12.81	6.10	4.90	2.10	1.25	2.329	8.67
June 1 . .	12.27	6.16	5.02	1.99	1.23	2.194	8.67
June 8 . .	11.98	5.96	4.98	2.01	1.20	2.190	8.16
June 15 . .	11.36	6.13	5.12	1.85	1.20	2.019	7.55

*Martin, Brown, and Sprague (2). Shape index = $\frac{2 \times \text{length}}{\text{width} + \text{thickness}}$

INFLUENCE ON VINE DEVELOPMENT

The weight of the vines was obtained for each sampling date as described above, and is given in Table II. The vines from the May 4 planting reached their maximum weight on August 31, but weighed more on August 10 than those from any other date. They declined rapidly after August 31, 2 weeks earlier than any other plots and 3 weeks earlier than June 15. The May 11 vines reached their maximum by August 24 and declined rapidly after September 14; May 18 vines reached the maximum by August 17, and declined rapidly after September 14; May 25 vines practically reached maximum by August 24, and declined after September 14. The vines from the May 25 planting were lighter in weight than those from any of the other dates except June 15, which probably accounts for the lower than expected yield. The reason for the smaller vines, however, might be explained by the fact that the month of May was one of the driest on record. No rain came until June 25. June 1 vines practically reached maximum by August 17 and declined after September 14. June 8 vines reached maximum by August 31 and also declined after September 14. June 15 vines reached maximum by August 24 and declined after September 21, which is 1 week later than any other plot and 3 weeks later than May 4.

An examination of vine growth during the last week in August shows May 4 best; May 11, second; May 18, third; June 1 and June 8 not much difference; May 25 and June 15 not much difference, but in fifth place.

The emergence dates show practically no difference; all plots came up in the fourth week after planting, requiring 22 to 26 days for emergence.

Planting Date	Blooming Date	Days After Planting
May 4	July 11	68
May 11	July 17	67
May 18	July 25	68
May 25	July 29	65
June 1	Aug. 1	61
June 8	Aug. 5	58
June 15	Aug. 11	57

The latest plantings bloomed slightly sooner after planting than the earlier dates.

The stand shows very little variation except for June 15. The stand was as follows: May 4, 84 per cent; May 11, 85 per cent; May 18, 85 per cent; May 25, 81 per cent; June 1, 83 per cent; June 8, 83 per cent; and June 15, 75 per cent.

The number of stems per hill would ordinarily be expected to increase with the later plantings. Such was not the case, however, this year. Storage conditions were excellent and sprouts even on the June 15 planting were just barely showing. The average number of stems per hill for 500 hills was as follows: May 11, 3.77 stems; June 1, 3.40; May 25, 3.23; May 4, 3.16; June 15, 3.14; May 18, 3.02; and June 8, 2.78.

The average height of vine for 30 hills shows that shorter vines are produced by later planting. May 4, May 11, and May 18 plantings all produced 30-inch vines; May 25 is again off with only 23-inch vines; June 1 is up to 25 inches; June 8, 26 inches, and June 15, 22½ inches.

EFFECT OF RATIO OF TUBERS TO VINES

The ratio of tubers to vines was calculated for each sampling date and is shown in Table II. This ratio shows the number of pounds of tubers produced per pound of vine, based on green weight. The May 25 planting proved to have the highest average ratio, which was due to the undersized vines as already noted. The May 4 planting was second, producing an average of 1.43 pounds of tubers for each pound of vine. The May 18 planting was third, followed by June 8, May 11, and June 1.

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Effect of Fertilizers in the Subsoil on Potato Roots

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ABSTRACT

This material will be published in full in the *American Potato Journal*.

POTATOES are usually shallow rooted on mineral soils in the eastern states. Loosening or artificially aerating the subsoil did not increase the depth of rooting on silt loam at Wooster. The addition of decomposed organic matter, lime, or phosphates to the subsoil distinctly increased the root development. It is suggested that the acidity of the subsoil is probably an important factor restricting root growth.

Three Years' Results With the Use of Copper, Manganese and Zinc Sulfate in Fertilizer Mixtures for Potatoes

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ABSTRACT

This paper will be published in the *American Potato Journal*.

FOURTEEN experiments with potatoes using 50 pounds per acre of sulfate of copper, of manganese, and of zinc and 75 pounds of a mixture of all three gave no significant increase in yield on the average trucking soils of eastern Virginia.

Soil Reaction, Available Nutrients and Composition of the Potato Plant

By ORA SMITH and L. B. NASH,¹ *Cornell University, Ithaca, N. Y.*

EXPERIMENTS have been conducted at Ithaca during the past 5 years, Smith and Moore (4) and Smith (5), on the effects of soil reaction on the growth, yield and market quality of potatoes. The data presented in this paper were obtained from the soil and plants of four of the 30 plots of this soil reaction experiment. The soil of these four plots is a silty clay loam with reactions in 1936 of pH 4.74, 5.65, 6.85 and 7.92. The reaction of the soil at the start of the experiment in 1932 was pH 5.6 to 5.8. The above reactions of pH 4.74, 5.65, 6.85 and 7.92 were obtained by the addition of sulfuric acid equivalent to 800 pounds of sulfur, 300 pounds of sulfur, 9,650 pounds of hydrated lime and 23,600 pounds of hydrated lime per acre respectively at various times during the period, 1932 to 1935.

Results of these studies show that the number of tubers set, size of tubers and yields are markedly reduced when grown in the more alkaline soils in comparison with those in the less alkaline or the acid soils. It is well known that the availability of certain mineral plant nutrients is largely dependent on the reaction of the soil or other medium supporting the plant growth.

Soils which have received heavy applications of lime or which have a high pH have been found in many instances to be deficient in soluble manganese or iron. There is some evidence also that the availability of potassium is decreased in heavily limed soils.

EXPERIMENTAL RESULTS

The average yields per acre in 1936 of the four ranges of reaction which include the above four plots were as follows: pH 4.74 to 5.04, 188 bushels; pH 5.13 to 5.63, 179 bushels; pH 5.67 to 7.04, 160 bushels; and pH 7.80 to 7.92, 104 bushels. The least difference required for odds of 19 to 1 by the analysis of variance method is 22.6 bushels per acre. Samples of soil were selected from each of the four plots on

TABLE I—SOLUBLE NUTRIENTS IN SOIL FROM POTATO PLOTS AS DETERMINED BY THE MORGAN TESTS (JULY 30, 1936)

Soil Reaction pH	Soluble Nutrients in Pounds per Acre*								
	Ca	P	NO ₃	NH ₄	K	Mg	Mn	Al	Fe
4.74	875	25	100	V.L.	S.T.	50	10	250	50
5.65	750	50	60	V.L.	0	100	7	50	35
6.85	875	100	85	V.L.	V.S.T.	175	0	15	35
7.92	3500	200	100	V.L.	M.T.	200	0	10	35

V.L. = Very low

S.T. = Slight turbidity

V.S.T. = Very slight turbidity

M.T. = Moderate turbidity

*Determinations made by Dr. E. V. Staker, Dept. of Agronomy.

¹Paper No. 156, Department of Vegetable Crops, Cornell University, Ithaca, N. Y.

TABLE II—PER CENT P_2O_5 IN POTATO MATERIAL ON DRY WEIGHT BASIS

Soil Reaction pH	Harvested August 4				Harvested August 24				Harvested September 16				Harvested October 10			
	Roots	Tubers	Stems	Leaves	Roots	Tubers	Stems	Leaves	Roots	Tubers	Stems	Leaves	Roots	Tubers	Stems	Leaves
4.74.....	.622	.945	.582	.785	.469	.876	.506	.585	.434	.914	.320	.406	—	.905	.326	.378
5.65.....	.564	.937	.552	.707	.478	.881	.459	.595	.385	.938	.468	.451	—	.887	.292	.337
6.85.....	.590	.872	.605	.670	.507	.901	.557	.647	.390	.871	.318	.401	—	.905	.264	.412
7.92.....	.711	.959	.656	.764	.530	.920	.771	.782	.251	.944	.497	.651	—	.942	.415	.559

TABLE III—PER CENT K_2O IN POTATO MATERIAL ON DRY WEIGHT BASIS

Soil Reaction pH	Harvested August 4				Harvested August 24				Harvested September 16				Harvested October 10			
	Roots	Tubers	Stems	Leaves	Roots	Tubers	Stems	Leaves	Roots	Tubers	Stems	Leaves	Roots	Tubers	Stems	Leaves
4.74.....	2.19	2.92	3.95	4.05	1.72	2.88	3.50	3.79	1.04	2.82	3.28	2.41	—	2.91	.901	.393
5.65.....	1.95	2.91	2.86	3.35	1.46	2.77	3.10	2.95	1.13	2.85	2.16	1.34	—	2.70	.339	.294
6.85.....	2.12	2.81	2.96	2.66	1.46	2.76	2.70	2.60	1.42	2.48	2.06	1.21	—	2.68	.721	.453
7.92.....	2.31	2.98	3.11	3.23	1.84	2.86	3.58	2.96	1.14	2.81	2.32	1.92	—	2.77	.586	.410

July 30, 1936 and the soluble nutrients determined by the Universal soil testing system of Morgan (3). The results of these determinations are presented in Table I.

The amount of soluble phosphorus and magnesium is lowest in the most acid soils and increases in the plots directly with the increase in pH of the soil. The amount of soluble calcium apparently did not vary in soils between pH 4.74 and pH 6.85. At pH 7.92, however, the amount of soluble calcium is very high. The amount of ammonia and potassium was too low at all reactions to be measured by this method. Nitrate nitrogen was abundant at all reactions, ranging from high to very high. Soluble aluminum and iron occurred in highest concentrations in the soils of lowest pH and decreased in quantity in the less acid and alkaline soils. Soluble manganese was found in low concentrations in soil of pH 4.74, very low in soil of pH 5.65 and could not be detected in soils of pH 6.85 and pH 7.92.

The results of these tests indicate that the soils of all four reactions possess sufficient soluble calcium, nitrate nitrogen, magnesium, aluminum and iron to support a large crop of potatoes. Phosphorus appears low at pH 4.74 but probably was high enough to support the yields obtained from that plot. Yields were highest at pH 4.74 and decreased as the phosphorus content of the soil increased in the soils of higher pH. Plots of pH 5.65, 6.85 and 7.92 apparently had sufficient available phosphorus to support yields greater than they produced. Ammonia was not present in sufficient quantities in any of the plots to be the cause of reduced yields. The highest concentration of soluble aluminum was found in the soil of pH 4.74. As this plot produced the highest yields it is unlikely that it was present in quantities sufficient to reduce the yields.

Soluble potassium was extremely low at all reactions and probably has curtailed yields in all plots. This fact, however, does not explain the much lower yields in the soil of pH 7.92 than in those of lower pH. Soluble manganese was present in low quantities at pH 4.74, very low at pH 5.65 and apparently entirely absent in soils of higher pH. The low yields of some of these plots may be attributed to the low supply of this nutrient. Still these data do not supply an explanation for the very marked difference in yield between the plots of pH 6.85 and pH 7.92, both of which show the absence of any soluble manganese by the above test. It is possible that the large quantity of available calcium may be a factor causing the lower yields. Midgley (2) concluded that the accumulation of large amounts of calcium salts was probably a contributing factor toward the lowered yields of some crops following overliming.

RELATION OF SOLUBLE SOIL NUTRIENTS TO PLANT COMPOSITION

The data of Table II show the percentage of phosphorus in the roots, tubers, stems and leaves of the potato plant when harvested at four stages of maturity. In 13 of the 15 sets of analyses the highest percentage of phosphorus on the dry weight basis was found in plants grown in the most alkaline soil, pH 7.92.

In considering plant analysis data, it should be emphasized that percentage composition based on the dry weight basis is oftentimes inadequate or even misleading, since the ash content of plants depends to some extent on the size of the plants or their stage of development. In some cases, stunted plants contain a higher content of ash than normal plants. In these experiments, however, when the phosphorus is calculated as percentage of the ash, the results are practically the same as when phosphorus was calculated as percentage of the dry matter. It is possible that plants grown in soil of high pH require larger amounts of soluble phosphorus for normal growth than those grown on soils less alkaline. McGeorge (1) concluded that plants require more soluble phosphate on alkaline than on neutral or slightly acid soils for normal growth. The soluble phosphorus content of the soil of pH 7.92 appears to be sufficiently high, however, to support normal growth in these experiments. These data indicate that phosphorus probably was not the factor limiting the yields in the soils of high pH.

The data on the percentage of potassium in the various plant parts are presented in Table III. In most instances the highest percentage of potassium was found in the plants which had been grown at pH 4.74 with a decreased amount in plants grown at pH 5.65 and pH 6.85 and then an increase in those plants grown at pH 7.92 over those grown at pH 5.65 and 6.85. When potassium is calculated as percentage of the ash, there is no lack of potassium at the higher pH which is disclosed by these data. The various portions of the plants grown at the high pH contain a high percentage of potassium in the ash.

It is possible that the low supply of available manganese is a causal factor contributing to the low yields obtained in the soils of high pH. The foliage of plants grown in soil of pH 7.92 is lighter green than that of plants grown at a lower pH. This indicates a probable insufficient supply of available manganese in the soil. Probably the yields would be increased in all plots by additions of potassium but the present data do not offer evidence that the soils of pH 7.92 would be benefited to a greater extent by such additions than the soils of lower pH. Data of further chemical analyses of the plant tissue should aid in the explanation of the lower yields obtained in the soils of high pH.

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The Influence of Fertilizers Upon the Yield and Starch Content of the Triumph Sweetpotato

By W. S. ANDERSON, *Mississippi Experiment Station, Laurel, Miss.*

IN connection with the Federal Emergency Relief Administration sweetpotato starch project at Laurel, Mississippi, experiments have been conducted during the past 2 years to determine the influence of commercial fertilizers upon the total yield of roots and starch content of the Triumph sweetpotato.

The work has been conducted on the three soil types usually planted to sweetpotatoes by growers in the Laurel area. These are Ruston fine sandy loam, Orangeburg fine sandy loam and Cahaba fine sandy loam. In 1935, plots were planted on very old and on new land of the Ruston Type. In 1936, only old Ruston was planted.

In all of the analysis work a total application of 800 pounds per acre was made. Nitrogen was varied in increments of 2 per cent from 2 to 8 per cent with phosphorus 8 and potash 4 per cent. Phosphorus was varied in increments of 4 per cent from 4 to 16 per cent with the nitrogen and the potash 4 per cent. Potash was varied in increments of 4 per cent from 4 to 16 per cent with the phosphorus 8 and the nitrogen 4 per cent.

In the rate work a 4-8-4 mixture was used. The rate of application was varied in some fields from 400 to 2,000 pounds per acre in increments of 400 pounds. In others it was varied from 500 to 2,000 pounds in increments of 500 pounds. When four treatments were used there were four replications, and when five were used there were five replications. In all cases the plots were distributed in a Latin square. Comparisons have been made of adjacent plots by the "Student" method of analysis of experimental data.

During the harvest 50 roots in each plot of every treatment were measured to determine the length/diameter ratio, since Schermerhorn (1) and Zimmerly (2) have found that fertilizers affect the shape of Little Stem Jersey and Porto Rico roots, and that apparently, chunkiness of roots is associated with high yields. A sample of 10 medium-sized roots was taken from each plot and within 24 hours from the time of digging, determinations were made of the starch and moisture content. For determination of the starch a polariscopic method (unpublished), developed by the Carbohydrate Research Division of the Bureau of Chemistry and Soils in connection with the starch plant project, has been used.

On moderately fertile Ruston land significant differences in total yield were obtained between 2 and 4 and between 2 and 8 per cent nitrogen. On fertile Orangeburg land that had been well cover-cropped for the 2 previous years, there was no difference of significance between any of the nitrogen treatments. On fertile Cahaba land there was a significant difference between the 2 and 8 per cent nitrogen treatments only.

In the phosphorus and potash treatments no differences of significance were obtained except between the 4 and the 16 per cent applications on the Cahaba and the very old Ruston lands.

TABLE I—INFLUENCE OF FERTILIZERS ON YIELD AND STARCH CONTENT OF TRIUMPH SWEETPOTATOES GROWN ON ORANGEBURG, RUSTON AND CAHABA LAND, 1935-1936.

Formula or Amount	Yield (Bushels per Acre) 2 Year Average				Per Cent Starch (Dry Basis)			
	Orange- burg	Ruston		Cahaba	Orange- burg	Ruston		Cahaba
		Old	New*			Old	New*	
Nitrogen								
2-8-4	345	214	255	357	71.69	73.95	82.19	75.40
4-8-4	326	227	249	369	73.68	73.07	86.78	74.49
6-8-4	320	249	262	367	75.27	73.77	87.71	76.06
8-8-4	329	260	307	399	72.87	72.02	83.61	77.71
Phosphorus								
4-4-4	305	221	246	295	73.94	75.30	77.22	70.77
4-8-4	298	262	265	322	73.17	74.86	75.00	71.43
4-12-4	306	263	263	342	74.54	74.86	80.46	71.99
4-16-4	312	264	261	321	70.63	76.77	74.25	75.94
Potash								
4-8-4	264	288	237	339	71.79	71.26	80.79	73.82
4-8-8	289	313	266	343	75.63	72.79	77.06	74.70
4-8-12	316	321	239	366	73.64	72.45	73.89	72.52
4-8-16	301	309	301	341	76.22	71.74	72.87	76.43
Rates of 4-8-4								
400	—	238	217	—	—	71.49	73.67	—
500	259	—	—	268	77.00	—	—	72.63
800	—	278	241	—	—	75.73	75.04	—
1000	307	—	—	286	82.04	—	—	76.16
1200	—	282	256	—	—	73.61	77.08	—
1500	298	—	—	316	82.50	—	—	74.75
1600	—	299	290	—	—	69.50	77.50	—
2000	305	301	337	319	77.46	74.22	72.59	76.74

*1935 only.

In the rates tests significant differences in yield were obtained between the 400 or 500 pounds and the higher applications in all cases except on the fertile Orangeburg land.

The data show that there was no effect by fertilizers upon the length/diameter ratio of the roots. However, Orangeburg land (which is more retentive of moisture) produced more chunky roots, regardless of fertilizer used, than Ruston or Cahaba land.

The data show that, though there were variations in starch content of roots produced on the different fields and even among treatments within each field, fertilizers apparently had no effect upon the starch content.

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Grade and Shape of Sweetpotatoes in Response to Potash in South Carolina

By VICTOR R. BOSWELL and J. H. BEATTIE, *U. S. Department of Agriculture, Beltsville, Md.*

INTRODUCTION

SCHERMERHORN (3) and Robbins and others (2) in New Jersey showed that the shape of the sweetpotato root as well as the yield was very markedly influenced by differences in potash supply, the root tending to be slender or stringy when potash was deficient and quite "blocky" or well-formed when well-supplied. Geise (1) in Maryland obtained a striking response in yield to potash fertilizer alone, and showed that the further addition of nitrogen or phosphorus, singly or both, produced but little additional yield over potash alone. Atlantic Coastal Plain soils are generally believed to require appreciable additions of potash for optimum yields of sweetpotatoes.

It was with these points in mind that the writers proposed to determine accurately to what extent the grade and shape of the sweetpotato were influenced by potash under commercial field conditions in another part of the Atlantic Coastal area—South Carolina. The question of the response of shape to environmental factors is an important one from the standpoint of variety description and identification, as well as from that of market grades.

The studies were conducted under a cooperative arrangement with the South Carolina Agricultural Experiment Station at its Pee Dee Branch Station at Florence, South Carolina, during 1929 to 1935, inclusive.

This report is but a brief summary of portions of extensive data that will be published later elsewhere.

METHODS

Exclusive of guard rows, the plots in 1929 to 1931 were 0.05 acre in size; in 1932 to 1935 they were 0.008 acre. Five fertilizer treatments were applied in 1929 to 1931; the fertilizer analyses were: 3-8-3,¹ 3-8-6, 3-8-9, 3-8-12 and 3-8-15. In 1932 to 1935 a 3-8-0 treatment was included. Treatments were replicated four times in 1929 to 1931 and five times in 1932 to 1935. All fertilizer applications were at the rate of 500 pounds per acre before planting. The first 3 years the plots were on moderately fertile land. Lack of very marked responses to the treatments suggested the presence of rather large fertilizer residues from previous crops, therefore the plots were established for the last 4 years on land known to be rather poor and which had been out of cultivation for a few years. During 1929 to 1931 only the Porto Rico variety was grown; in the later years Nancy Hall and Big Stem Jersey were included to determine whether varietal differences in response might exist.

¹3 per cent nitrogen, 8 per cent phosphoric acid and 3 per cent potash.

TABLE I—EFFECT OF POTASH IN FERTILIZER ON PERCENTAGE OF TOTAL YIELD OF SWEETPOTATOES IN EACH U. S. GRADE

Year	K ₂ O in Fertilizer (Per Cent)	Per Cent of Total Yield in Grade Indicated			Total Yield Per Acre (Bushels)
		Jumbo (Per Cent)	No. 1 (Per Cent)	No. 2 (Per Cent)	
<i>Porto Rico Variety</i>					
1929 ..	3	8.8	75.8	13.4	205
	15	9.8	79.5	10.7	233
1930	3	6.4	74.8	18.8	241
	15	11.2	73.8	15.0	243
1931	3	16.6	64.4	19.0	130
	15	35.6	48.9	15.5	129
1932	3	12.2	46.8	41.0	96
	15	24.5	45.8	29.7	115
1933.....	3	0	69.2	30.8	177
	15	11.4	65.0	23.6	180
1934.....	3	16.3	70.2	13.5	198
	15	21.0	66.6	12.4	192
1935 ..	3	8.0	58.4	33.6	106
	15	18.2	50.0	31.8	133
Mean	3	9.1	63.8	27.1	165
1932-35	15	18.3	58.7	23.0	175
<i>Nancy Hall Variety</i>					
1932	3	14.6	54.5	30.9	91
	15	16.2	58.3	25.5	109
1933	3	0	65.5	34.5	219
	15	0	65.1	34.9	222
1934.. . . .	3	9.4	73.0	17.6	244
	15	14.2	70.2	15.6	238
1935	3	19.4	54.3	26.3	183
	15	22.5	49.4	28.1	158
Mean	3	9.7	63.9	26.4	184
1932-35	15	12.0	62.3	25.7	182
<i>Big Stem Jersey Variety</i>					
1932 ...	3	2.7	54.7	42.6	91
	15	7.1	50.0	42.9	96
1933	3	0	64.6	35.4	188
	15	0	56.8	43.2	197
1934	3	0	82.0	18.0	239
	15	1.8	81.3	16.9	238
1935 . . .	3	11.7	48.6	39.8	142
	15	13.9	56.0	30.1	144
Mean	3	2.8	67.0	30.2	165
1932-35	15	4.5	65.8	29.7	171

Upon harvesting, the yield of each plot was graded into Jumbo, U. S. No. 1 and U. S. No. 2 grades and each grade weighed. Measurements for determining shape indices were made of only the roots from the 3-8-3 and 3-8-15 plots. All Jumbo roots from these plots were measured in all years. In 1932 to 1935 the entire yield from these two treatments was measured, but in the first 3 years the plots were so large

that only a sample of random baskets of graded roots was taken for measurement. Neither the weights of these samples nor the total number of roots in the No. 1 and No. 2 grades were recorded. Thus for the years 1929 to 1931 there is no basis for calculating the mean indices for entire crops, No. 1 and No. 2 grades or for combinations of years.

In the 7 years' work approximately 30,000 roots were measured from 72 "pairs" of plots involving three varieties and two different general soil conditions.

All means shown are true means, not means of grade percentages or yearly mean values. The shape index used here is the quotient of length divided by maximum diameter.

RESULTS

Table I shows that in every year of the study high potash produced in the Porto Rico variety a greater proportion (by weight) of Jumbos and a smaller proportion of No. 2 grade than did low potash. In some years differences were negligible, but for the 7-year period the difference was doubtless significant. In general the proportion of No. 1 grade was slightly lower for high potash, because the increase in Jumbos was greater than the decrease in No. 2's. The actual yield of No. 1's and the total yield were not consistently different between the two treatments.

In the Nancy Hall and Big Stem Jersey varieties there was a much less pronounced tendency than in Porto Rico for the Jumbo grade to increase or for the No. 2 grade to decrease in response to additional potash. The small percentage of Jumbos is not surprising to those who are familiar with the growth and development of these varieties, but the lack of definite response otherwise is noteworthy as shown by the practically unchanged relationships in grades 1 and 2. The similarity in yield per acre of the two treatments is contrary to the majority of evidence on potash requirements of this crop in the Atlantic Coastal area. Under these conditions there was no significant difference in total yield due to fertilizer in seasons of either high or low yield.

Table II presents the shape indices for three crops grown on fertile land and Table III for four crops on poor land. Contrary to expectations based on earlier publications (2, 3), table II shows, in some instances, higher shape indices (proportionally more slender roots) from the high potash than from the low potash treatment. This was true for

TABLE II—SHAPE INDICES OF U. S. GRADES OF SWEETPOTATOES AS INFLUENCED BY POTASH IN FERTILIZER (FERTILE SOIL, 1929-31)

Grade	K ₂ O (Per Cent)	1929 (Index)	1930 (Index)	1931 (Index)	Mean (Index)
Jumbo	3	1.733 ± .0257	1.654 ± .0187	1.641 ± .0306	1.684 ± .0141
	15	1.770 ± .0259	2.267 ± .0316	1.478 ± .0219	1.828 ± .0173
No. 1	3	1.615 ± .0112	1.911 ± .0149	1.624 ± .0087	—
	15	1.876 ± .0123	1.886 ± .0134	1.508 ± .0112	—
No. 2	3	2.174 ± .0222	2.345 ± .0165	1.971 ± .0142	—
	15	2.341 ± .0262	2.341 ± .0190	1.594 ± .0155	—

all grades of the 1929 crop and the Jumbo grade of 1930. It thus appeared that the earlier observations in New Jersey might have been based on conditions not generally found elsewhere. These results in Table II were obtained with the Porto Rico variety, which in shape is quite different from Big Stem Jersey that was used in the New Jersey work.

Table III shows that without exception as to grade or variety the 4-year means of the shape indices were smaller for the high potash treatment than the low, on poor soil. On account of space limitations, data for individual plots and years have been omitted, but it should be stated that in numerous instances this relationship between treatments was reversed for similar grades within a single replication. The means for the entire 1935 crop of Nancy Hall and the 1934 and 1935 crops of Big Stem Jersey were also exceptions, although the means for individual plots were inconsistent in their relations to potash.

TABLE III—FOUR-YEAR MEAN SHAPE INDICES OF THREE GRADES OF FOUR VARIETIES OF SWEETPOTATOES AS INFLUENCED BY POTASH IN FERTILIZER (POOR SOIL, 1932-1935).

Variety	K ₂ O in Fertilizer (Per Cent)	Portion of Crop Measured			
		Jumbo Grade (Index)	No. 1 Grade (Index)	No. 2 Grade (Index)	Total Crop (Index)
Porto Rico	3	1.947 ± .0388	2.175 ± .0116	2.979 ± .0192	2.546 ± .0120
	15	1.741 ± .0272	2.072 ± .0103	2.792 ± .0182	2.382 ± .0109
Nancy Hall	3	1.770 ± .0362	2.230 ± .0097	3.072 ± .0186	2.555 ± .0107
	15	1.704 ± .0243	2.163 ± .0096	2.877 ± .0181	2.436 ± .0103
Big Stem Jersey	3	2.108 ± .0639	2.387 ± .0112	3.069 ± .0194	2.697 ± .0116
	15	2.009 ± .0515	2.244 ± .0097	3.037 ± .0185	2.598 ± .0109
Mean of 3 varieties	3	1.892 ± .0248	2.268 ± .0063	3.041 ± .0110	2.601 ± .0070
	15	1.764 ± .0176	2.164 ± .0057	2.901 ± .0106	2.474 ± .0062

It might be contended that a deficiency of some factor other than potash prevented a typical response to increased potash. Yields of 175 to 240 bushels per acre, however, in 1930, and 1934 suggest no serious nutritional deficiencies. It rather appears that even on the supposedly poor land where these crops were grown, no important potash deficiency existed. The question then is more strongly presented than before, as to how generally applicable and commercially important are the results obtained in New Jersey. Our results again emphasize the regional and perhaps even the local nature of certain nutritional problems, and the need for large numbers of experiment fields well distributed over the important regions of production of a specific crop.

CONCLUSION

Applications of 75 pounds versus 15 pounds per acre of K₂O (500 pounds of 3-8-15 versus 3-8-3) on Norfolk fine sandy loam soil in South Carolina resulted in very slight and somewhat inconsistent differences in the length/diameter ratios of sweetpotato roots. The higher

potash produced somewhat larger roots as shown by the larger percentage of Jumbo and smaller percentage of No. 2 grades of roots, with the percentage of No. 1 grade showing little change. Four years' data from three varieties on poor soil resulted in a mean shape index of $2.601 \pm .007$ for low potash and $2.474 \pm .006$ for high potash. The difference is highly significant statistically but of doubtful importance because of its small magnitude. Three years' study of the Porto Rico variety grown on more fertile soil gave rather contradictory and inconclusive results with reference to root shape, but the effects of potash on grade agreed with the results obtained on poor soil.

Under the conditions of these studies, increasing the potash content of the fertilizer from 3 to 15 per cent had no important effect on total yield, yield of No. 1 grade, or on the shape of sweetpotatoes. It did however slightly increase the size of the roots as shown by a slightly increased percentage of the Jumbo grade.

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The Extent and Rate of Soil Moisture Depletion in Loess Soils by Asparagus and Rhubarb¹

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ALFALFA and fruit trees have been found to remove moisture at great depths (1, 2). In many mature orchards and vineyards planted on the loess hills in eastern Nebraska very little available moisture exists in the top 20 or 30 feet (2). The time has seemed opportune to determine the extent and depth to which perennial vegetables as asparagus and rhubarb could remove moisture from these deep soils.

Soil samples were secured with steel tubes to a depth of 20 feet on October 10, 1935 in a 14-year-old and an adjacent 5-year-old asparagus plantation on the higher portion of typical rolling loess soil located along the western edge of Omaha. For purposes of comparison, samples were secured in a 33-year-old grape vineyard adjacent to the asparagus on the uphill side and from a tract on the down hill side that has had only annual crops. The rhubarb plantation which was down the hill below the annual crop area was mulched with straw. This one set of holes was in a straight line with less than 200 feet between extremes. About 100 feet away a duplicate set of holes was made in parallel position. Susequent sampling was done at intervals during the record breaking hot dry summer of 1936. A portion of both asparagus plantations was irrigated in 1936 by the overhead system, all water passing through a meter, so as to permit additional studies on water use and rate of removal by asparagus. The soil absorbed water rapidly and none ever ran off even though 7 to 11 inches were applied at one time in continuous day and night runs. Losses due to evaporation before the water got to the ground were high in July and August but cannot be estimated with any degree of accuracy.

For the purpose of this discussion the various technical terms are used in accordance with the following meaning: "Total moisture" is the moisture found in a soil when dried at 104 degrees C for 48 hours, calculated as per cent of dry weight of soil. "Hygroscopic coefficient" is the percentage of moisture that a dry soil will absorb in 24 hours in a saturated atmosphere at a temperature of 25 degrees C (3). "Calculated field moisture holding capacity" was derived by arbitrarily assuming that the hygroscopic coefficient of soil is 40 per cent of the total field moisture holding capacity ($HC \times 2.5$). This figure is similar to the moisture equivalent and is sometimes referred to as "total wetness". "Calculated available soil moisture holding capacity" was derived by subtracting the HC from the value secured for the calculated field moisture hold capacity. "Available moisture found in the soil" was calculated by subtracting the HC from the percentage of moisture found in the soil at sampling time. "Percentage that the available moisture in the soil was of the calculated available water capacity" was

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secured by dividing the latter value into the value for calculated available moisture. This might be considered as showing the extent to which the soil was still filled with available moisture or the degree of wettness. "Available moisture as inches of water" was determined by dividing the percentage of available water in any foot by 6.5, which has been found to be approximately the percentage of soil moisture that is equivalent to 1 inch of water.

It was hoped that the data from the area used for "annual vegetables" could be used as an index of the field moisture holding capacity of the soil. However, this does not seem advisable because the percentages of available moisture actually found in the upper 11 feet appeared to be much too low when compared either with the calculated available moisture holding capacity or the available moisture found in the asparagus plats after irrigation in 1936. Evidently some of the annual crops grown on this land during the last few years were sufficiently deep rooted to remove moisture down to the 11th foot.

If the calculated values for available moisture capacity are in error they are probably slightly high in the upper and low in the lower portion of the 20 foot cores. On a calculated basis these soils were found to hold 45 to 50 inches of water in the top 20 feet or an average of 2.5 inches per foot. The term "effective precipitation" indicates that the only precipitation considered was that amounting to .25 inch or more occurring in one day or two consecutive days. This probably gives values too high rather than too low because of run off in sudden downpours or off of frozen ground.

In both asparagus plantations the available moisture was very seriously depleted in the two upper 5-foot regions and 30 per cent had been

TABLE I—MOISTURE AVAILABLE TO PLANTS, AS FOUND IN THE SOIL UNDER VARIOUS CROPS

Soil Depth (Feet)	October 10, 1935					October 16, 1936		
	Asparagus		Rhu- barb*	Grapes*	Annual Vegeta- bles*	Asparagus		Grapes
	Old	Young				Old	Young	
<i>Available Moisture in the Soil as Per Cent of Total Available Moisture Capacity</i>								
1-5	24.3	6.1	48.9	51.3	71.8	15.0	24.9	20.0
6-10	20.4	35.3	56.1	36.9	81.6	7.0	18.6	20.8
11-15	70.5	69.2	86.7	52.1	90.9	46.8	67.1	41.4
16-20	94.1	105.8	90.2	76.8	90.0	76.6	98.9	80.2
1-20	50.8	51.4	70.1	52.0	88.2	35.0	50.4	39.7
<i>Available Moisture in the Soil as Inches of Water</i>								
1-5	2.9	0.8	6.2	6.7	9.1	1.8	3.1	2.6
6-10	2.4	4.1	6.6	4.8	9.9	0.8	2.2	2.7
11-15	8.0	8.2	10.2	6.7	10.8	5.3	8.0	5.5
16-20	9.9	10.5	10.7	8.9	11.3	8.0	9.8	9.3
1-20	23.2	23.6	33.7	27.1	42.1	15.9	23.1	20.1

*Asparagus and grape data are based on 1 hole each, that for rhubarb and annual vegetables on 2 holes. Data from duplicate holes that were secured in October 1935 with asparagus and grapes are not reported. They were practically identical with the data reported from single holes.

removed from the third 5-foot zone prior to October 1935 (Table I). In the older plantation some may have been removed from the fourth 5-foot zone. While about 51 per cent of the moisture still remained in the top 20 feet only about 20 per cent was found in the top 10 feet.

There was no rain worth consideration from June 26 till August 19, 1935, consequently the tops of the larger plants in the old plantation were seriously damaged. From August 19 to September 8 there were 3.53 inches of effective rainfall, which the old plants were unable to utilize because of their damaged condition. The plants of the young plantation being smaller were still green and removed practically all of the late moisture before October 10, thus accounting for the great deficiency of moisture in the top 5 feet of soil in the younger plantation.

In the rhubarb plantation where plants were in fair condition the moisture was definitely depleted to a depth of 12 or 13 feet with approximately half of the available moisture still remaining in the top 10 feet. The depletion was most serious in the 3 to 8 foot levels. These plants could not remove all available water for it was never below 18 per cent of the available capacity of any one foot. In the drouth of 1936 it was necessary to irrigate this plantation in July to prevent its complete destruction and further data were not obtained.

Grapes removed more moisture in the lower 10 feet and less in the upper 10 feet than did asparagus. The total moisture available in the top 20 feet was about the same with the crops, but with grapes more of it was near the top. This vineyard was still in a reasonably productive condition.

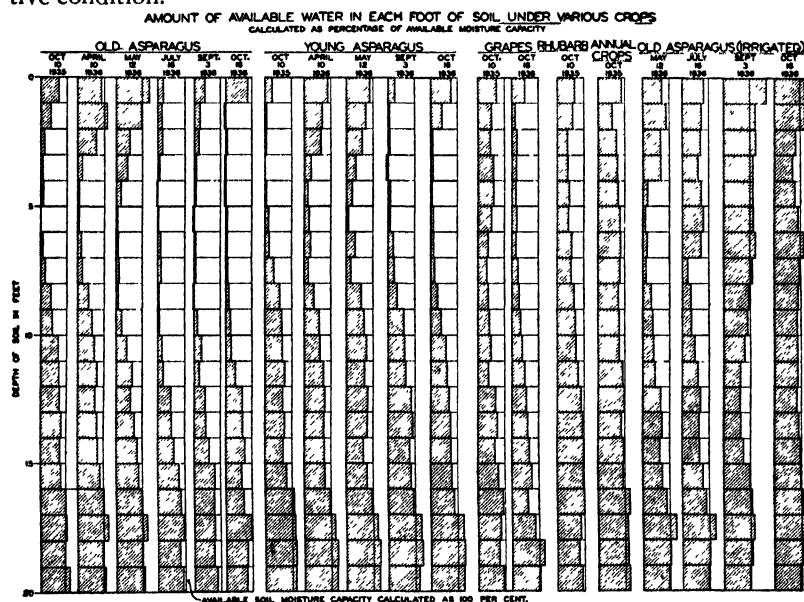


FIG. 1. Amount of available moisture present in each foot of soil calculated as percentage of the available moisture capacity in asparagus plantations and under other crops at various times throughout a period of one year.

During the winter of 1935-36 the soil moisture in the upper 3½ feet of the old asparagus field was replenished by the effective precipitation calculated as 6.1 inches which increased the total moisture in the soil by 5.22 inches (Table II). There was an additional acquisition of water in the upper 4½ feet of soil during the first month of the cutting season, up to May 12, but simultaneously moisture had been removed in the 8- to 14-foot zones (Fig. 1) so that the soil now contained only 2.51 inches more moisture than in October 1935. Cutting for market ceased about June 25 and tops then grew rapidly. Between May 12 and July 16 the temperature was unseasonably high. The water usage of 14.79 inches during this period was much in excess of the precipitation so that the top 20 feet of soil contained 6.47 inches less water on July 16 than during the previous October. This moisture was removed from the top 5 feet, which were thus almost depleted, and from the 9th to 20th feet. After July 16 the tops of the plants made little or no growth and they were damaged considerably during this, the hottest summer on record, with drouth conditions continuing till August 18. As a result of this reduced top size, perhaps accompanied by a degree of drouth resistance in the tissues, and the scarcity of water close to the surface, the moisture loss was less than earlier in the summer but the deficit below October moisture was increased to 9.01 inches. During this period the moisture from rainfall disappeared quickly and about an equal amount of water was taken out of the 13th to 20th feet. By September 3 the soil from 3 to 10 feet inclusive was practically devoid of available moisture. With cooler weather during September and until October 16, less water was used than was absorbed from

TABLE II.—TOTAL AMOUNT OF MOISTURE FALLING UPON SOIL AS EFFECTIVE PRECIPITATION OR IRRIGATION, ALSO TOTAL AMOUNT OF WATER USED* AND NET GAIN OR LOSS IN SOIL MOISTURE FROM OCTOBER 1935 TO VARIOUS DATES IN 1936 IN THE UPPER 20 FEET IN TWO ASPARAGUS PLANTATIONS. (ALL DATA CALCULATED AS INCHES OF WATER SINCE OCTOBER 10, 1935)

Sampling Date in 1936	Non-irrigated			Irrigated		
	Effective Precipitation	Water Used	Soil Moisture Net Change	Effective Precipitation and Irrigation	Water Used	Soil Moisture Net Change
<i>Old Asparagus Plantation</i>						
April 10.....	6.10	0.88	+5.22	6.10	0.88	+5.22
May 12.....	7.74	5.23	+2.51	11.71	7.71	+4.00
July 16.....	13.55	20.02	-6.47	28.94	20.42	+8.52
September 3...	16.51	25.52	-9.01	51.16	28.58	+22.58
October 16.....	21.61	28.76	-7.15	63.31	41.58	+21.74
<i>Young Asparagus Plantation</i>						
April 10.....	6.10	0.13	+5.97	6.10	0.13	+5.97
May 12.....	7.74	0.56	+7.18	12.79	1.22	+11.57
July 16.....	13.55	Not sampled		29.80	16.92	+12.88
September 3...	16.51	17.17	-0.66	32.76	28.53	+ 4.23
October 16.....	21.61	21.98	-0.37	47.00	31.82	+15.18

*Water used might be stated as water disappearing after falling on the soil as it includes losses due to run off and evaporation as well as that removed by the plants.

rain. During this period the dessication of the top 3 feet was completed but a rain a few days before the final sampling replenished the moisture in the top foot. Very little moisture was removed below the 4th foot. Although the total soil moisture deficit since October was reduced slightly it still amounted to 7.15 inches, the total water loss having been 28.76 inches with effective rainfall at 21.61 inches. Apparently asparagus can and does remove all the available moisture out of a soil zone before it draws very heavily on deeper zones.

The young asparagus plantation with smaller plants did not use as much water as the older one. The relatively small losses in this plantation prior to April 10 and May 16 are thought to be due to peculiarities of topography which probably permitted a small amount of run off from higher land on to this plat during heavy spring rains. In the younger plantation moisture was not removed to as great a depth as in the older plantation and only 5 feet of soil (2 to 6 feet) were quite completely dried out. The water loss from the young plantation was only 21.98 inches or only 0.37 inches more than the calculated effective precipitation. This loss is approximately three-fourths as great as in the old plantation. The top growth of the young plantation held a similar ratio to that of the old plantation (Table III).

TABLE III—TOP GROWTH OF ASPARAGUS BY OCTOBER 10, 1936

Factor Considered	Unirrigated		Irrigated	
	Old	Young	Old	Young
Total number of stems (10 plants)	106	81	242	84
Total dry weight 10 plants (pounds)	4.8	3.6	10.4	5.5

In the irrigated portion top growth was not increased appreciably until after mid August. At that time there was a sudden increase in growth in stems formed earlier but most growth occurred in a large number of new stems (Table III). The severe heat of midsummer with the consequent high demands for respiration may have inhibited metabolism sufficiently to prevent the earlier development of the buds necessary for the formation of these stems.

In the old plantation irrigation was such that it practically filled the upper 4 feet by May 12, 7 feet by July 16, 12 feet by September 3 and 17 or 18 feet by October 16. In this irrigated plat the plants lived on the current rainfall and irrigation water, the soil moisture at any level never having been reduced below the amount present in the spring. The irrigated plants used very little more water than those not irrigated until after July 16 when, as a result of water being readily available and top growth having been greatly increased (after August 15), the water usage was very much greater than in the unirrigated plats.

The irrigated portions of the old and young plantations used 41.6 and 31.8 inches of water respectively, so that even though 41.7 and 25.4 inches of water were supplied by irrigation the gain in soil moisture accounted for only 21.7 and 15.2 inches respectively. This usage in both irrigated plats was about 45 per cent greater than in the corresponding unirrigated plats.

In the grape vineyard (unirrigated) which was pruned back severely in the winter, 27.08 inches of water or 7.03 inches in excess of rainfall were lost from the soil during the year. Although the grapes removed as much water as the old asparagus it never exhausted the soil moisture as completely as did asparagus and the percentage of available moisture never was reduced below 13 per cent of the available capacity.

SUMMARY

In a 15-year-old asparagus plantation on loess soil 65 per cent of the available soil moisture was removed from the top 20 feet. Complete removal of available moisture progressed downward as the season advanced or the plantation grew older. Practically all available moisture was removed to a depth of 10 feet. A 6-year-old plantation used less water and did not remove it to so great a depth. Moisture is apparently used extravagantly when available, as 41.6 inches of water was used in 1936 when irrigated, in contrast with 28.8 inches when not irrigated. Whenever the moisture supply in the upper several feet of soil was sufficient for the needs of the plant asparagus did not remove moisture from the lower levels into which roots had previously penetrated. Roots of rhubarb apparently did not penetrate beyond the 13th foot, did not reduce the moisture below 38 per cent of the available capacity and seemed to be less drouth enduring than asparagus. A 34-year-old grape vineyard removed 60.3 per cent of the available moisture in the top 20 feet and although the water usage in 1936 was as great as by the old asparagus plantation, the available moisture was never reduced by grapes below 13 per cent of the available capacity in any one zone.

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The Anatomy and Histology of the Transition Region in *Capsicum Frutescens*

By H. L. COCHRAN and F. F. COWART, *Georgia Agricultural Experiment Station, Experiment, Ga.*

ABSTRACT

This paper will be published in full in the *Journal of Agricultural Research*.

THIS study was made to determine the method of root-stem transition in *Capsicum frutescens* and to note the similarity, if any, to that of some other closely related species of Solanaceous plants, several of which have been reported.

The first indication of a change from the exarch condition of the root to the endarch condition of the stem occurs in the uppermost portion of the root. This change is the breaking up of the diarch xylem plate with the pith becoming evident, and the beginning of a bifurcation of the two xylem strands. At or immediately above this position the two phloem groups split up into three strands each.

In the lower portion of the hypocotyl, about 2.5 centimeters below the cotyledons, the central group of phloem cells on either side differentiates inward and form the internal phloem. At a level just below the divergence of the cotyledons internal phloem groups come to lie on the inner face and external phloem groups on the outer face of each of the metaxylem strands.

About 2 millimeters below the cotyledonary plate there is a gradual separation of the two bundles formed by the breaking up of the original diarch xylem plate. One of these double units consisting of one protoxylem point and its two lateral metaxylem groups together with the internal and external phloem groups becomes the vascular trace of one of the cotyledons, and the second unit, that of the other. Inward differentiation of the protoxylem with an orientation of the metaxylem and phloem group eventually lead to the establishment of the bicollateral condition. The complete transition from root to stem structure is not attained in the hypocotyl but at a point about 5 millimeters out in the midrib of the cotyledon.

The method of root-stem transition in *Capsicum frutescens* is essentially the same as that of several other previously reported members of the Solonaceae.

Results With Rapid Soil Tests Used on the Plots of a Vegetable Fertilizer Experiment.

By JOHN D. HARTMAN, *Cornell University, Riverhead, N. Y.*

THERE seems to be little reason to question the value of rapid soil tests in diagnosing troubles in greenhouse and other very intensively used soils, where fertilizer applications are large and where absorption and leaching of nutrients are such great unknown factors in fertilizer practice. The author's experiences during 1935 and 1936 seem to show that quantities of available nutrients in greenhouse and similar soils vary through such wide ranges that it is easy, with soil tests, to recognize deficiencies, abundances and excesses. Hundreds of tests have shown, however, that under ordinary Long Island field conditions, differences in available nutrients between apparently deficient soils and soils which, according to plant response, seem to have sufficient supplies of all nutrients are frequently not remarkably great. For this reason it seemed desirable to study the accuracy and the meaning of the test results by using the tests on soil from permanent plots where ordinary amounts of different fertilizers are applied and where test results could be correlated with yields determined largely by known soil deficiencies.

The results presented in this paper were obtained during 1936 on the plots of a vegetable fertilizer experiment which was started in 1923 and which has been conducted under the direction of P. H. Wessels. The experimental area, which covers about 2½ acres, is located at the Long Island Vegetable Research Farm, Riverhead, New York. The arrangement of plots of the original treatments is presented in a forthcoming Cornell Bulletin entitled "Tomato Fertilizer Experiments on Long Island". Rates of application of fertilizers on some plots were increased in 1932, but the old plan shows satisfactorily the size and shape of plots and the distribution of replicates and checks. The soil on this experimental area is classified as Sassafras silt loam. It has not been irrigated.

Soil samples were taken with a soil sampling tube at six different places on each plot. Only the upper 6 or 7 inches were sampled. After sampling, the soil was air-dried fairly rapidly on greenhouse benches. Although it seems desirable to test samples immediately after they are taken, it also appears that it is in many cases impractical to attempt to do so, especially when one is testing samples for county agents. After drying, the samples were stored in a dry room and were later screened and thoroughly mixed in a rotary mixer.

All tests were made in test tubes 15 mm in diameter. Colors and turbidities were estimated by comparisons with color standards consisting of alcoholic solutions of mixtures of three very stable dyes¹ and a suspension of 200-mesh plaster of Paris in alcohol. The standards were also made up in 15 mm test tubes. All tests were made at about 19 to

¹The dyes were Zapon Fast Scarlet CR, Zapon Fast Yellow Gr, and Zapon Fast Blue 3G, sold by the General Dyestuff Corp, 230 Fifth Ave., N. Y. The author is indebted to Mr. Kenneth Hankenson, of the Quality Lime Institute, for suggesting the use of these dyes.

22 degrees C and comparisons with color standards were judged by artificial light. The reagents were frequently tested on known solutions. In most cases the quantities of soil extract and of reagents were measured accurately with burettes.

The samples were tested for nitrate nitrogen, ammonia nitrogen, phosphoric acid, potash, aluminum and iron, and pH. Hydrogen-ion concentrations were determined electrometrically. For other determinations 20 grams of dry soil were thoroughly shaken up with 50 cc of 0.1 per cent (by weight or volume) acetic acid and then separated again from the solution by filtering. Phosphoric acid was determined also on extracts made with 50 cc of 0.19 per cent (by weight) citric acid and 2 grams of soil and, in the case of the June samples, on extracts of 2 grams of soil with 50 ccc of 0.1 per cent acetic. Outlines of directions used in making the tests are as follows:

Nitrate nitrogen

- .5 cc soil extract
- 6.0 cc diphenylamine reagent, Morgan (3)
- Shake thoroughly and make reading in 2 minutes.

Ammonia nitrogen

- 1 cc soil extract
- 4 drops Nessler's reagent (3)
- Shake thoroughly and read after 3 or more minutes.

Phosphoric acid

- 1.00 cc soil extract
- .25 cc molybdate solution (10 grams ammonium molybdate, 100 cc HCl, 50 cc HNO₃ made up to 500 cc with distilled water.)
- 1 small piece of tin
- Shake and read as soon as color develops to the blue-green shade of the standards.

Potash

- .5 cc soil extract
- 1.1 cc 95 per cent ethyl alcohol
- Shake well
- .5 cc Morgan's potassium reagent A (3)
- Shake well and read any time after 4 minutes.

Aluminum and iron

- 1 cc soil extract
- 2 drops ten times concentrated Dahlberg and Brown extracting solution, Hester (2)
- 5 drops hematein solution (3)
- Shake well and read color after 8 or 10 minutes.

Tests were made only once, except in determining phosphoric acid after the citric extraction and after the 50:2 acetic extraction. These phosphoric acid tests were done twice. As previously stated, it was a main purpose of the work here reported to study the accuracy of the tests when used in the same way as by the author in diagnosing troubles for growers. At time of testing, the fertilizer applications of the plots

were not known; unless some peculiarities in the reactions themselves were noted at the time of testing, tests were never repeated.

In 1935 and 1936 the plots of the fertilizer experiment were divided in half by lines running north and south. In 1935 the east sides of the plots were fertilized early in the spring and planted with spinach and lettuce. The west sides were fertilized in June and planted to lima beans and Brussels sprouts. In 1936 fertilizer was broadcast over the west sides of the plots on April 23. The east sides of all plots, except those receiving manure, were left unfertilized. Manure had previously been applied to both sides of the manure plots and plowed under. In the following text, yields and rapid test results from the west sides of the plots are referred to as from the fertilized halves of plots and those from the east sides as from unfertilized halves, regardless of the fact that in 1936 there were no differences in treatment between the two sides in the cases of the manure plots and of certain plots which never receive any fertilizer or manure.

Three rows of spinach were sown on part of the unfertilized half and three rows on the fertilized half of each plot. On the fertilized half two rows of lettuce were also planted. Soil samples were taken on March 25, 1936, April 25, and June 20. No rain fell between the time of applying fertilizer and the second date of sampling. Severe drought stunted both spinach and lettuce throughout May and the first part of June. On June 13 and 14 a total of 4 inches of rain fell. The spinach was harvested on June 17 and 18 and the lettuce on July 10.

Fig. 1 shows that the tests indicated very little nitrate nitrogen present on any plots in March or in June, after the heavy rains, or in April on the unfertilized plots. From the April samples medium tests for nitrate nitrogen were obtained on most plots where nitrate had been applied. Only in the case of the plots receiving 60 pounds of nitrate nitrogen was the average amount of nitrate found unexpectedly low. The explanation for this discrepancy is probably in the occasional failure of the diphenylamine to develop color with normal rapidity in the presence of nitrates. Although, as mentioned, the east and west sides of the manure plots were manured equally,

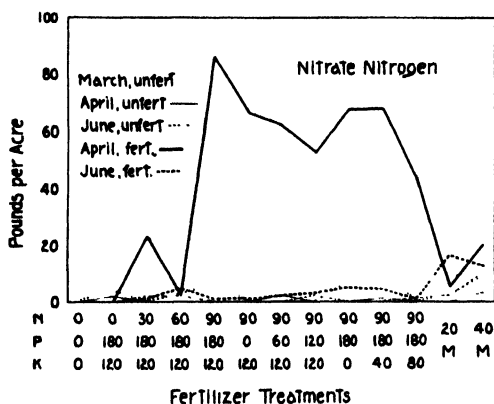


FIG. 1. Average amounts of nitrate nitrogen found on the three plots of each treatment. The fertilizer treatments, in terms of amounts of nitrogen, phosphoric acid, and potash applied per acre, are indicated below the graph, in line with the symbols for nitrogen (N), phosphorus (P), and potassium (K), respectively. The term, pounds per acre, when used with reference to quantities of fertilizing materials, means pounds per two million pounds of soil.

test results as well as yields were somewhat higher on the west sides in most cases. This difference may be attributable to the green manuring effect of the large Brussels sprout plants which grew on the west sides of the plots in 1935.

Figs. 2 and 3 show amounts of phosphoric acid indicated by two different methods of extraction. The amounts indicated by the citric extraction are often 20 or 30 times as great as with the 50:20 acetic

extraction. When, however, the amount of phosphoric acid is very large by the acetic extraction, the amount indicated by the citric extraction is not proportionally large. The average amount of phosphoric acid indicated by either test seems to bear a fairly close relationship to the amount of phosphoric acid which has been applied each year. In most cases the 1936 addition of phosphoric acid is reflected by a higher test, in the April and the June samples, on the fertilized halves of plots which received phosphoric acid.

The 50:2 acetic extraction on the June samples ordinarily indicated the presence of about eight to fifteen times as much phosphoric acid as was found by the 50:20 acetic extraction on the same samples. On samples which tested very low or very high by the 50:20 extraction, however, results with the 50:2 extraction tended to be not proportionally low or high.

Fig. 4 shows that potash tested low on plots which have received little or no potash during the past 13 years. The tests

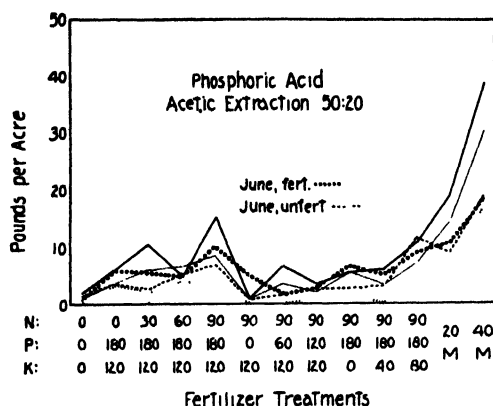


FIG. 2. Average amounts of phosphoric acid found on the three plots of each treatment; 50:20 acetic acid extraction. March and April determinations are indicated by the fine dotted line and the solid lines, as they are in Fig. 1.

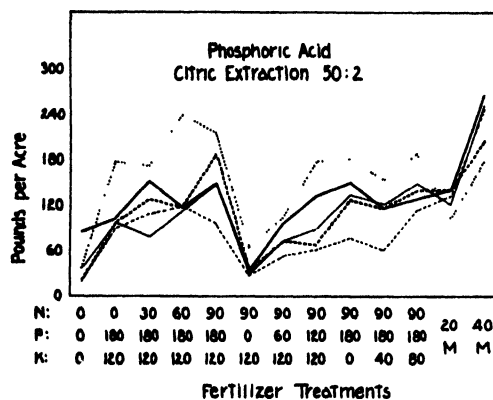


FIG. 3. Average amounts of phosphoric acid found on the three plots of each treatment; 50:2 citric acid extraction. The different kinds of lines represent results from different sets of determinations, as indicated in Fig. 1.

mentioned, regardless of the fertilizer treatment. This method of studying data is described by Ezekiel (1) and is called cross-classification or sub-sorting. The yields of fertilized spinach were, for example, tabulated according to the amounts of nitrate nitrogen, phosphoric acid by the citric extraction, and potash found on March 25, 1936. The same yields were then tabulated according to nitrate nitrogen, phosphoric acid by the 50 to 20 acetic extraction, and potash found on March 25, and again, according to the nutrients found by the different extractions on April 25 and on June 20.

In tabulating, all nitrate tests higher than 50 pounds per acre were classified as high; all from 15 pounds per acre to 50, medium; all from 3 to 15, low; and all below 3 pounds per acre, very low. Corresponding values for other classes used in the headings of the tabulation sheets were as follows:

Phosphoric acid (50:2 acetic extraction)

Very low	0 —	2.4 pounds per acre
Low	2.5 —	6.0 pounds per acre
Medium	6.1 —	14.0 pounds per acre
High	14.1 —	50.0 pounds per acre

Phosphoric acid (50:2 acetic extraction)

Very low	0 —	12 pounds per acre
Low	13 —	24 pounds per acre
Medium	25 —	72 pounds per acre
High	73 —	170 pounds per acre

Phosphoric acid (50:2 citric extraction)

Very low	0 —	24 pounds per acre
Low	25 —	72 pounds per acre
Medium	73 —	160 pounds per acre
High	161 —	360 pounds per acre

Potash

Very low	0 —	24 pounds per acre
Low	25 —	99 pounds per acre
Medium	100 —	159 pounds per acre
High	160 —	540 pounds per acre

As pointed out above, plots of none of the treatments showed appreciable quantities of nitrate nitrogen in the March and June samples. There would obviously be very little correlation between yields and nitrates found on those dates. So, in tabulating the yields according to the March and June tests, the known applications of nitrate nitrogen were substituted for the nitrate test results.

In sub-sorting, a number of yield figures commonly fell in the same space in a table. All figures belonging in one space were then averaged. This means that in many cases several plots showed, by test, the same nutrient supply and that the yields from such plots were averaged. The yields thus grouped together were then handled as replicates of single treatments, and by removing variance (in R. A. Fisher's sense, 4) due to treatment and using the proper number of degrees of freedom, gen-

eralized standard errors of individual replicates were calculated. These were compared with standard errors of individual replicates resulting when variance due to actual fertilizer treatments was removed and with those obtained when no variance due to treatment was removed. Standard errors which were comparatively small indicated that yields were closely correlated with certain soil test results, or were closely correlated with known fertilizer applications.

CONCLUSIONS

From a careful study of the standard errors it appeared that the following conclusions might be drawn:

1. It is not worthwhile to make a special extraction for phosphoric acid, either with 0.19 per cent citric acid or with 50 cc of 0.1 per cent acetic acid used with 2 grams of soil.

2. Determinations of phosphoric acid and potash on the March soil samples were as accurate for indicating available nutrients, which during the season influenced yields, as were the April or the June determinations. However, if yields of fertilized spinach, as well as of unfertilized spinach had all been sub-sorted in one table, instead of separately, doubtlessly the June determinations would have given much lower errors than the March determinations would have. The March determinations give fairly reliable indications of relative yields to be expected on different fertilized halves of plots, because the 1936 treatments were the same as the previous treatments. Where the 1936 treatments were different on different parts of plots previously similarly treated, as in the case of the halves fertilized and unfertilized, the June or April results would doubtlessly have been needed to obtain close correlation between available nutrients and yields on the different halves.

3. Although the standard errors were usually higher when the plots were grouped according to soil test results than when they were grouped according to known fertilizer treatments the differences were not great. In other words, there was almost as much variation among plots having the same fertilizer treatment as among plots showing approximately the same nutrient levels by the soil tests. This means that although one finds fairly frequent lack of similarity in yield in different areas giving the same tests and lack of yield differences in the right direction between adjoining areas giving definitely different test results, he should not at once conclude that the tests are of little value for his conditions. It must be remembered how frequently similar discrepancies occur among plots of similar or dissimilar fertilizer treatment. On the other hand, a large difference in yield between good and poor areas in a field is necessary before any nutrient difference shown by a single pair of test results may be used to account for it. In this experiment, if differences in yield were of about 22,000 pounds per acre for lettuce, about 5,700 pounds for fertilized spinach and about 3,000 pounds for unfertilized spinach, if quantities of one nutrient were definitely different, and if other test

results and observed conditions were the same, it was probable (30 to 1) that the difference in yield was due to that difference in nutrient level. Quantities of nutrients were considered about the same only when they were within the range of one of the aforementioned classes used in tabulations.

Among the undetermined soil variables which in this experiment were probably partially responsible for yield discrepancies are boron content, manganese content, moisture-supplying power, aeration, oxidation-reduction potential, soil texture and depth of surface soil.

These experiments have been done on one soil type. The range in yields as well as in quantities of nutrients found is not nearly so great among the plots receiving only commercial fertilizer as would have been found if many soil types had been used. On the other hand, by using only one soil type the influence of the above mentioned undetermined soil variables is minimized. It may be desirable, when attempting to diagnose soil troubles, always to get a sample from better as well as from poorer areas in the same field or same soil type. If testing is done on such pairs or groups of samples, the data given above make it seem probable that extreme differences in availability of nitrate nitrogen, phosphoric acid and potash can easily be detected and cases of mild deficiency may often be reliably identified.

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Some Effects of Potassium on Yields of Snap Beans

By J. MITCHELL JENKINS, JR., *South Carolina Truck Experiment Station, Charleston, S. C.*

IN fertilizer experiments at the South Carolina Truck Experiment Station it was found that beans responded positively to applications of nitrogen and phosphorus but failed to show increases in yield from any of the potassium treatments. In most cases actually reduced yields occurred wherever potash was used. It was assumed that the reductions in yield were due to the injurious effect of potash fertilizers upon the roots of the bean seedlings, but later observations showed that the root systems were apparently normal, while stands were not significantly lower on potash plots than on those which had received no potash. All of the fertilizer mixtures had been applied seven days before planting time and were thoroughly mixed with the soil, so there had been little danger of injury to the germinating seed from toxic salt concentrations, especially as the potassium had been derived from potassium sulphate.

Sayre and Clark (1) concluded that under the conditions of their experiments muriate of potash and sulphate of potash were no longer injurious to bean seeds and produced no root injury after 2 days in the soil, but kainit and manure salts contain large quantities of other soluble salts and maintained a toxic concentration in the soil solution up to 9 days. Hester (2), working in the Norfolk area, states that since potash is so generally used it is felt that only in isolated cases has potash become a limiting factor. Miller and Kimbrough (4) found that small applications of potash were beneficial at Louisiana State University in the spring, while at Houma the addition of potash was of doubtful value. According to Thompson (3) authorities agree that the mineral elements, phosphorus and potash are of the greatest importance, and on sandy loam soils of low productivity an application of 800 to 1,000 pounds of a 5-10-5 mixture is none too heavy for a crop of early snap beans.

To determine the reason for the negative reaction of snap beans to applications of potash in the Charleston, South Carolina area replicated plots were laid out in randomized blocks and the following treatments were applied:

Plot	Treatment and Source	Pounds of Available K. per Acre
1	No potash	0
2	5 per cent potash)	50
3	7 per cent potash) from KSO_4	70
4	10 per cent potash)	100
5	5 per cent potash from KCL	50
6	5 per cent potash from $\frac{1}{4}\text{KCL}$ and $\frac{1}{2}\text{K}_2\text{SO}_4$	50
7	5 per cent potash from KNO_3	50
8	5 per cent potash from kainit	50

Stand counts were made of all plots and yield records were obtained in each case. The plots were tested for available potash before the ex-

periments were begun and at the conclusion of the tests, and acidity readings were taken of all plots. The soil was classified as a Norfolk sandy loam and it ranged in acidity from pH 5.5 to pH 5.0 which is fairly typical for soils in the Charleston area.

RESULTS

The mean yield of beans for the 3-year period from plots which had received no potash was 418.25 pounds, while plots which had received the common commercial application of 50 pounds of available K_2O yielded 411.25 pounds. Lowest yields resulted from the use of 100 pounds of potash, or 377.31 pounds of marketable beans as compared to 418.25 pounds from the "No potash" plots (Table I).

TABLE I—YIELDS OF SNAP BEANS FROM DIFFERENT POTASH TREATMENTS*

Year	Treatment, in Pounds per Acre			
	No potash	50 Pounds K_2O	70 Pounds K_2O	100 Pounds K_2O
Spring 1934	418.0	389.5	366.5	326.5
Fall 1934	433.25	426.5	412.0	401.0
Spring 1935	474.75	500.5	445.75	463.25
Spring 1936	347.0	328.5	325.5	318.5
Mean	418.25	411.25	387.43	377.31

*A significant difference between any of the above is 22.95 pounds per plot.

An analysis of variance showed that there was no significant difference in yield between the "No potash" treatment and 50 pounds of available potash, but both 70 and 100 pounds of available K_2O gave significantly lower yields than "No potash" or 50 pounds of potash.

Stand counts of the various plots showed no consistent differences, although there was a poorer stand some years on plots which had received high applications of potash. Even in years when the stand was fairly uniform over all of the plots there was a decided decrease in yield from plots which had received potash applications.

Tests of different sources of potassium resulted in no significant differences in yield where the fertilizers were placed in bands to each side of the bean seed at time of planting. When placed in the row and mixed with the soil prior to planting, however, kainit gave much lower yields than other forms of potash. The mean yield of beans from the kainit plots was 52.0 pounds as compared to 80.3 from potassium chloride and 85.5 pounds from potassium sulphate. There was no significant difference in stand between kainit and potassium sulphate and it was assumed that the difference in yield was due to toxic effects of the kainit salts.

Table II shows typical potash readings for the plots on which the experiments were run as well as readings from commercial plantings of beans.

From the above table it will be seen that even where no potash was applied in 3 years the amount of available K_2O ranged from 180 to 300 pounds per acre, while readings ran as high as 400 pounds where applications of potash were made each year. The relatively high amounts

TABLE II—RESULTS OF SOIL TESTS FOR AVAILABLE POTASH

Sample Number	Fertilizer History	Pounds of Available Potash per Acre (According to LaMotte Test)
1	Field plot—No potash for 3 years . . .	200
2	Field plot—No potash for 3 years . . .	300
3	Field plot—No potash for 3 years	220
4	Field plot—No potash for 3 years	180
5	Field plot—100 pounds K_2O each year	400
6	Field plot—100 pounds K_2O each year	220
7	Field plot—100 pounds K_2O each year	350
8	Field plot—100 pounds K_2O each year	350
9	Commercial bean field (5-7-5 fertilizer)	400
10	Commercial bean field (5-7-5 fertilizer)	350
11F	Fallow field—Not fertilized in 4 years . . .	300

of potash available in the soils may be explained by the fact that truck growers have consistently used fertilizers analyzing 5 per cent to 10 per cent available potash in this district, and the usual application is 1,000 to 2,500 pounds per acre, depending on the crop to be grown. Some years as much as 200 pounds of available potash per acre has been supplied to a single field in 12 months' time, since two to three crops can be grown each year in the Charleston area on a given piece of land. Few vegetable crops use more than 90 pounds of available K_2O per acre and it is probable that a reserve of potassium has been built up in the soils in question, due to the fact that the crops commonly grown would not be able to utilize all of the potash that is supplied them each year.

Tests have shown that an average crop of snap beans removes from 16 to 20 pounds of available potash from each acre. It must be concluded, therefore, that there is ample available potash in most soils in the Charleston area for the needs of the bean crop, due to past fertilizer practices, and that for this reason beans failed to respond to additional potash in the fertilizer mixture and yields were actually reduced in direct proportion to increases in the amount of available K_2O supplied.

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The Effect of Fertilizer Placements and Analyses on the Growth and Yield of Certain Truck Crops

By M. M. PARKER, *Virginia Truck Experiment Station, Norfolk, Va.*

THE true value of any given fertilizer element, or mixture of elements, as a supply of plant nutrient may be obscured in many field fertilizer experiments because, in conducting the experiment, the placement of the material has been such that factors other than supplying a given amount of nutrient have become involved. These factors may take such form as interference with the germination of the seed, and the subsequent reduction in number of plants contributing to the yield; severe seedling root injury from which the plant may recover, but not sufficiently early to off-set the handicap; or formation of a root system not conducive to the most effective utilization of the nutrient and moisture content of the soil. The latter factor applies more specifically to cases in which an incomplete fertilizer is used and where the omitted nutrient must be furnished by the natural soil supply.

An experiment was conducted in 1936 to compare the effectiveness of increasing amounts of potash and phosphorus in fertilizer mixtures when placed in various positions relative to the seed or plant set in the field. The mixtures used were as follows: A potash series consisting of 6-6-0, 6-6-5, and 6-6-10 mixtures, and a phosphorus series consisting of 6-0-5, 6-6-5, and 6-12-5 mixtures. Three fertilizer placements were used on Bountiful snap beans and four on Copenhagen Market cabbage plants set in the field.

RESULTS WITH SNAP BEANS

The five fertilizer mixtures used on Bountiful snap beans were applied at the rate of 1,000 pounds an acre in the three following placements: (a) Broadcast at the time of planting; (b) fertilizer placed in bands by machine 2 inches to each side and 2 inches below seed level; and (c) placed by hand in a band 4 inches wide and 3 inches below the seed. The experiment was conducted on a Norfolk sandy loam soil low in nitrogen, phosphorus, and potash. Each treatment consisted of a row 97 feet long replicated four times in randomized blocks.

Potash Series:—Fig. 1 presents the effect of increasing amounts of potash on the germination and yield of snap beans when this element was used in conjunction with constant amounts of nitrogen and phosphorus. Germination of the seed took place when the moisture content of the soil was low, consequently fertilizer injury was unusually severe where the materials were placed in a band 4 inches wide and 3 inches below the seed level. In this position the mixture containing 10 per cent potash was most destructive to germination, only about one-third of the seed having germinated. When the amount was applied broadcast germination was slightly affected, but the least injury resulted when the potash was placed in bands on each side of the seed. Five per cent potash also severely affected the germination when the mixture was

placed beneath the seed, but the damage was less than that caused by the 10 per cent mixture. When either broadcast or used in bands to the sides of the seed, the 5 per cent potash in the fertilizer had no injurious effects on germination and gave an increase in yield over that obtained with the fertilizer without potash.

The yield of beans secured from the potash series of fertilizers placed beneath the seed was apparently inversely correlated with the injury to germination. This may be summed up in the statement that the higher the potash content, the lower the germination, and the smaller the yield.

The yields obtained from the side placement of fertilizers containing 5 and 10 per cent potash were slightly lower, but not significantly so, than from the broadcast application; presumably because of the effect of placement on the root formation. Greenhouse studies of bean roots as influenced by the placement of the fertilizer have shown that bands of fertilizer cause the roots to be largely restricted to the area of more abundant plant nutrients compared with a well-distributed root system obtained by mixing the fertilizer with the soil. Thus, the plants with the restricted root systems were not able to utilize the limited supply of soil moisture available at the time of the test to as great an extent as those with the dispersed root systems obtained where the fertilizers were broadcast.

Phosphorus Series:—As shown in Fig. 2 the mixtures containing various amounts of phosphorus were also decidedly injurious when placed beneath the seed. The injury was practically non-existent, however, when the materials were placed in bands on the sides of the seed and only slightly injurious when broadcast.

The yield of beans resulting from placing the phosphorus series beneath the seed, like that obtained from the similar placement in the potash series, was correlated with seed injury. Broadcasting this series resulted in slightly better yields than placing them to the sides of the seed, which again was probably due to the difference in root formation.

The best yields were obtained from the mixtures containing 6 per cent phosphorus and 5 per cent potash. The use of larger amounts of these nutrients was detrimental when placed in bands to the sides of the seed and under the conditions of this experiment to a lesser extent when broadcast, but placement of any of the fertilizers beneath the seed

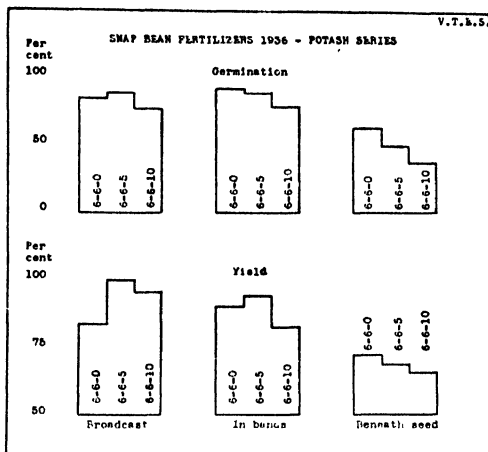


FIG. 1. The effect of the placement of potash fertilizers on the germination and yield of snap beans.

was very injurious. Yields were low when no phosphorus was included in the mixture.

RESULTS WITH CABBAGE

The four fertilizer placements used on cabbage were as follows: (a) 1,000 pounds applied in a 12-inch mark, mixed with the soil by means of a cultivator, and covered with a furrow of soil before setting

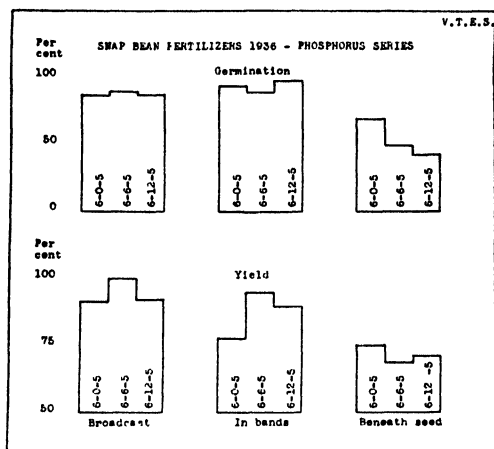


FIG. 2. The effect of the placement of phosphorus fertilizers on the germination and yield of snap beans.

the plants, followed by 1,000 pounds as a sidedresser; (b) 2,000 pounds mixed with the soil before planting as in "a", no sidedresser; (c) 1,000 pounds in bands on each side of the plant followed by 1,000 pounds as a sidedresser; and (d) 2,000 pounds in bands as in "c" without the sidedresser. The yields obtained from these treatments are shown in Table I.

Mixing the fertilizer with the soil in the row before setting the plants gave higher yields than did the application in

bands on each side of the plants. Since soil moisture was the limiting factor during the greater portion of the growing period, it is believed that the poorer growth which occurred where the plants were fertilized in bands was due to a greater localization of the root system which was less adapted to the utilization of soil moisture. Kale roots reacted in a similar manner to fertilizer placement in the greenhouse studies and it is logical to assume that the same type of root growth would result from these placements on cabbage.

Where fertilizer was mixed with the soil in the row, the maximum yields were obtained with 5 per cent potash, but where the fertilizer was concentrated in bands to the sides of the plant at the time of planting the maximum benefit was obtained from the 10 per cent application. The greater response to the higher percentages of potash in the fertilizer applied in bands was probably due to the fact that the concentration of the root area in this type of placement limited the utilization of the residual potash in the soil to a greater extent than where the fertilizer was distributed over a wide area and the root system was more extensive.

The response to phosphorus was more marked, irrespective of the type of placement, than was the response to potash. Omitting phosphorus from the fertilizer mixture had a decidedly more depressing effect on growth where the fertilizer was applied in bands than where

mixed with the soil. Here, as in the case of potash, the accumulation of roots in the vicinity of the bands tended to prevent optimum utiliza-

TABLE I—THE INFLUENCE OF VARIOUS FERTILIZER ANALYSES AND THEIR PLACEMENT ON THE YIELD AND QUALITY OF SPRING CABBAGE 1936*

Placement: Potash Series	Yields in Tons per Acre†				Average Head Weight Pounds
	6-6-0	6-6-5	6-6-10	Average	
1000 pounds mixed with soil + 1000 pounds sidedresser	10.69	12.40	12.29	11.79	2 20
2000 pounds mixed with soil	9 74	11.93	11.16	10.94	2.14
1000 pounds in bands + 1000 pounds sidedresser	9.61	9.54	10.67	9.94	1.84
2000 pounds in bands	8.80	9.20	10.69	9 56	1.96
Average tons per acre	9.71	10.77	11.20	—	—
Average head weight pounds.	1.90	2.06	2.15	—	—

Placement: Phosphorus Series	Yields in Tons per Acre†				Average Head Weight Pounds
	6-0-5	6 6 5	6 12-5	Average	
1000 pounds mixed with soil + 1000 pounds sidedresser	6.64	12.40	12 71	10.58	2.06
2000 pounds mixed with soil	5.83	11.93	11 12	9.63	1.97
1000 pounds in bands + 1000 pounds sidedresser	4.14	9.54	10 80	8.16	1.65
2000 pounds in bands	3.44	9.20	9 99	7.54	1.72
Average tons per acre	5.01	10.77	11.16	—	—
Average head weight pounds	1.31	2.06	2.18	—	—

*Cabbage plants set in the field March 27, 1936. Harvested July 6, 1936. Rainfall during season 10.59 inches.

†Each yield indicated represents an average of four replicates.

tion of the residual phosphorus in the soil. The fact that the plats treated with 1,000 pounds of fertilizer in bands at planting, with a later sidedressing of 1,000 pounds, gave better growth with a 6-0-5 mixture than did the entire amount applied in bands tends to verify this belief. There was a significant increase in yield of cabbage with as high as 12 per cent phosphorus in the fertilizer where the material was applied in bands plus a sidedresser, but where it was mixed with the soil, no significant increase was obtained when the content exceeded 6 per cent.

Distinctive Effects on the Growth of the Tobacco Plant When Certain Mineral Nutrients are Deficient

By J. E. McMURTREY, JR., *U. S. Department of Agriculture,
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ABSTRACT

This material has been published in part in *U. S. D. A. Tech. Bul.* 340.

THE presentation consisted of a series of transparencies in natural color illustrating mineral nutritional deficiency effects in tobacco and a verbal explanation and discussion of the distinguishing features of the several deficiency effects.

The tobacco plant manifests distinctive effects when the soil in which it is growing is deficient in any one of the several elements essential to development. A reduction in growth results when any of the essential elements is deficient but typical pathological symptoms also are evident on close inspection which serve to distinguish one deficiency from the other.

A deficiency of nitrogen is characterized by the entire plant assuming a light green color, followed by more or less yellowing and drying or "firing" of the lower leaves to a light brown color. A shortage of phosphorous, in contrast, results in a plant that is abnormally dark green in color and if firing takes place the dried leaves are dark brown. A shortage of potassium or magnesium, in contrast with nitrogen and phosphorous deficiency, produces a plant showing localized effects, with chlorosis of the lower leaves as the dominant characteristic. Typical potassium hunger is distinguished from magnesium hunger by the appearance of small necrotic spots at the tip and margins of the chlorotic leaves which usually do not occur in the case of the latter.

In contrast with the deficiency effects of the above-mentioned elements are those typically occurring on the new growth or bud leaves and caused by shortages of iron, manganese, sulphur, boron and calcium. Shortages of iron, manganese and sulphur do not result in death of the terminal bud as is the case with calcium and boron but produce distinctive types of chlorosis. Iron chlorosis and manganese chlorosis resemble each other in that the veins tend to retain their green color, but in the case of manganese deficiency a necrotic spotting occurs scattered over the leaf while typically no necrotic spots are associated with iron deficiency. The chlorosis resulting from sulphur deficiency differs from that just described in that the veins are of a lighter green color than the leaf tissue between the veins. Boron and calcium deficiency effects differ from each other in the early stages. A shortage of calcium first becomes apparent as a peculiar hooking downward of the tip of the young leaves of the terminal bud, followed by death of the young leaves at their tip and margins, and if later growth takes place the tip and margins of the leaf are missing, giving a leaf with a cut-out appearance at the tip and margins. In contrast with this effect, a shortage of boron is shown in a light green color at the base of the young leaves of the bud,

followed by their breakdown which, if not too severe, is followed by later growth, which produces a twisted or distorted leaf. In conclusion the discussion was summarized by presentation of a key constructed on the basis of the above-mentioned contrasted effects.

All the above-mentioned deficiencies except iron have been observed on the tobacco plant in the field in connection with studies of plant food requirements of this crop.

Potassium and Calcium in Relation to Nitrogen Metabolism

By G. T. NIGHTINGALE, *University of Hawaii, Honolulu, Hawaii*

ABSTRACT

This material will be published in the *Botanical Gazette* for March, 1937.

THIS paper reviews briefly metabolic changes in stored organic nitrogen and the new synthesis of organic nitrogen in relation to potassium and calcium metabolism.

The Use of Borax in Controlling Dark Center of Turnips

By GRANT B. SNYDER and RALPH W. DONALDSON, *Massachusetts
State College, Amherst, Mass.*

THE appearance of water core or dark center within the roots of rutabagas has for years been a problem of major importance to many growers who supply the market with this crop for human consumption. Affected roots are objectionable for cooking on the basis of poor appearance, texture, and mashing quality. Presence of dark center is not confined to the New England States. It has been reported from such widely distributed regions as the Maritime Provinces and British Columbia in Canada, sections of Ireland and in the westland region of New Zealand.

SYMPTOMS

Dark center is known by the trade as brown heart, water core, black heart, water heart, mottled heart, and punky core. It can only be detected by cutting into the root. In the field there is no definite outward indication of the disorder although most roots affected show a slight russetting or roughness of the skin. The leaf growth of affected roots is identical to that of a normal healthy plant.

On cutting the root the condition is manifested by definite brownish or water-soaked areas at irregular intervals in the parenchyma tissue. These areas are more pronounced from the point of the medulary strand to the primary xylem in the lower half or below ground part of the rutabaga. The upper part of the root is usually slower to show typical symptoms. The disorder is practically never apparent in the cortex or cambium region.

In the advanced stages the water-soaked appearance practically disappears leaving a greyish brown, dry, punky mass of central tissue in which definite cracks appear, or the parenchyma tissue may become definitely punky or pithy. It is at this stage that the roots are noticeably light in weight and have a very woody texture. There is nothing to indicate or suggest that dark center is of parasitic origin. The disorder so far as present investigations indicate is due to a physiological or perhaps chemical disturbance within the root brought about by an unbalanced nutritional and water condition. Dark center invariably appears toward the end of the growing season and regardless of the size of root. After the first indications of the conditions the amount of tissue affected increases very rapidly; a week frequently being sufficient to ruin an entire crop as a marketable product.

The lack of any readily observable external symptoms for detecting sound from affected roots renders the marketing of any but comparatively clean crops unsatisfactory.

OBSERVATIONS AND INVESTIGATIONS ON CONDITIONS INFLUENCING DARK CENTER

Dark center is common in practically all commercially grown varieties of rutabagas. There is some evidence, however, that certain locally developed strains are somewhat resistant. This is especially true of the

variety Macomber. The true turnip does not show the characteristic water-soaked area but rather becomes definitely pithy or punky and therefore does not exhibit symptoms of dark center as recognized in the Rutabaga or Swede turnip.

Extensive observations of field plantings in various sections of Massachusetts over a period of 5 years indicated that the presence or absence of dark center could not be identified with any one specific condition. It occurred on all types of soil from the heavy glacial till type of Berkshire County to the sandy water-laid soils of Cape Cod. Commercial fertilizers of varying grades, applied in variable quantities and in different ways had no apparent influence. The amount of affected tissue could not, in an apparent manner, be associated with seasonal fluctuations of weather. From all of these field observations the only points of significance were (a) where seaweed was used in abundance in pit storage in the field, the roots of the plants growing immediately over such pits the following year were relatively clean. (b) Clean roots were observed quite frequently on raw subsoil brought to the surface during the previous year's pitting operation and (c) plants grown on soil where manure had been piled produced roots which were quite free of dark center.

These factors as noted in the fields of a large number of commercial operators were substantially corroborated when studied under controlled conditions in the greenhouse. The controlling factors therefore seemed to be limited to an involved relationship of water or of some minor element of nutrition.

The first definite clue from the minor element viewpoint came from Dr. D. J. MacLeod of the Dominion Experiment Station, Fredericton, New Brunswick, Canada, who in 1933 in trials with boron obtained roots free of dark center. Following this investigation other Canadian stations undertook similar work and reported favorable results for amounts of 10 pounds per acre of borax applied in the row with other fertilizer provided the soil was not of a neutral or alkaline reaction. Dr. Chukka of Maine also obtained excellent control of dark center with borax during his field trials of 1934 and 1935. He reported fair control of the condition on the plots where seaweed was used.

In the spring of 1936 Professor Donaldson, Extension Agronomist at the Massachusetts State College, in preliminary pot studies in the greenhouse found no indication of injury from borax to the germinating seedlings of rutabaga to amounts up to 30 pounds per acre (highest used) when applied as either a spray or mixed in the soil. The soil used was taken from Berkshire County (a heavy loam) and from Cape Cod (a light, Merrimac, sandy loam).

On the basis of results from these preliminary studies Professor Donaldson established 10 field demonstration plots in five Massachusetts counties. Commercial powdered borax was used in all cases and the applications varied in rates per acre from 8 to 30 pounds. The borax was applied in some cases as a spray along the seed row after seedage and in other cases drilled in the seed row prior to seedage with a Planet, Jr. seeder. Where this seeder was used discs Nos. 13, 14, and 15 delivered respectively 8, 10, and 13 pounds of "Mule" brand borax per acre from machines 300 and 310A.

The results of some of these field trials are outlined in the following specific cases. Mr. S. R. Morrison of Windsor prepared 11 acres of a heavy loam soil by using 20 tons of manure and 500 pounds of a 4-16-20 commercial fertilizer per acre. Fifteen pounds of borax per acre was applied as a spray (4 row traction sprayer) just after emergence of the seedlings except for four rows where 30 pounds per acre were applied. No dark center roots were found on the treated areas whereas the check rows ran 33 per cent affected. The roots from the treated area also were finer textured and of a better quality than those from the untreated area. This same field in 1935 produced 15 cars of rutabagas out of which only two were free from dark center.

In Plymouth County a field having a medium loam soil was treated with 10 pounds of borax applied as a delayed spray at the time the roots were fairly well formed. The crop from the treated area had 40 per cent of the roots slightly affected while the untreated area had 100 per cent of the roots severely affected with dark center. While the delayed spray appreciably reduced the damage, full control was not obtained because the borax was applied too late in the maturity period of the crop or the amount used was insufficient.

In Barnstable County (Cape Cod) the plots were all located on farms having a loamy, coarse, sandy soil. On the farm of Mr. S. Childs 10 pounds of borax were drilled in prior to seedage for his entire commercial planting. This same grower on smaller plots applied pulverized borax at rates varying from 8 to 26 pounds per acre. On his commercial, as well as on his smaller plots, positive control was obtained whereas on the check plots 75 per cent of the roots were affected. In the same region Mr. George Brackett, who plants from 20 to 25 acres annually drilled in commercial borax prior to seedage at the rate of slightly less than 10 pounds on an area of 15 acres. For his soil this amount was apparently insufficient in that practically no difference was evident between the treated and untreated areas. On an adjacent field, however, 20 pounds per acre of borax gave complete control of dark center.

These various field trials of borax, while not complete as to amount of boron required or methods and time of application, did definitely indicate that:

- (a) Borax will control dark center of rutabagas; (b) boron is deficient in many soil areas of the state if dark center of rutabagas is a fair indicator of such a deficiency; (c) ordinary soil amendments commonly used by the grower do not supply sufficient boron to prevent dark center; and (d) from 10 to 20 pounds per acre of borax applied as a powder or spray completely controlled dark center of rutabagas on the varied soils of Massachusetts if applied in drill. When borax is applied broadcast 20 to 30 pounds were indicated.

The observations made during the past year indicated further that more work must be done (a) to determine the effect of repeated application of borax on soils in order to study the rate of fixation and leaching. (b) To determine the most practical procedure in supplying boron to soils as a spray, powder, or pulverized material and whether it can be combined and applied effectively in a complete fertilizer.

Cauliflower Browning Resulting From a Deficiency of Boron¹

By C. H. DEARBORN, H. C. THOMPSON and G. J. RALEIGH, *Cornell University, Ithaca, N. Y.*

IN 1935 Dearborn and Raleigh (1) gave a brief report of field studies on cauliflower browning made in Delaware County, New York. They described the trouble as follows: "Discoloration first appears as small, concentric, water-soaked areas in the stem and in the center of the small branches of the curd. The affected head is bitter in flavor, both in the raw and in the cooked state. Although browning usually is associated with hollow stem, many fields of cauliflower with hollow stems have been found to be free of the browning. When browning is severe the outer, as well as the inner, portion of the head is involved. Rusty brown areas appear on the surface of the curd and in this stage it is known locally as brown rot or red rot."

A survey made in 1934 on 150 farms in Delaware County showed that about 30 per cent of the cauliflower crop was so affected that it was not marketable. This resulted in a loss of about \$50,000 to the growers in Delaware County.

Results of experiments conducted on 24 farms indicated that surface browning could be controlled by application of borax (the decahydrate $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$) at the rate of 1.25, 2.5 and 5 pounds to the acre applied in trenches 4 inches to the side of the row and 4 inches deep. Five other minor elements used in the experiment had no apparent effect on browning.

The results of the field experiments mentioned were so striking that it seemed desirable to check them under more nearly controlled conditions in the greenhouse.

EXPERIMENTS IN GREENHOUSE

An experiment was started in a greenhouse at Ithaca in the fall of 1935 using soil (Lackawanna silt loam) from a field in which browning was serious in the summer of 1935. The reaction of the soil, as measured by the quinhydrone electrode, was from pH 6.4 to 6.5 at the beginning and from pH 6.4 to 6.7 at the end of the experiment. Twelve-inch clay pots, previously paraffined, were used as receptacles for these plants. These pots were filled with the soil and a 4-8-7 fertilizer, made up of Baker's chemicals, was applied at the rate of 1 ton to the acre. This fertilizer was thoroughly mixed with the surface 4 inches of soil. This soil had been fertilized with 2 tons of a 4-8-7 commercial fertilizer in the spring of 1936. There were 6 lots, of 10 pots each, differing only in the quantity of borax added, as shown in Table I. A good strain of Super Snowball cauliflower was used and 60 well-grown plants were set in the pots, one plant to the pot. These plants were grown to maturity in the pots in a greenhouse where the temperature was held between 60 and 70 degrees F.

¹Paper No. 161, Department of Vegetable Crops, Cornell University, Ithaca, New York.

TABLE I—EFFECT OF BORAX ON GROWTH OF CAULIFLOWER PLANTS IN GREENHOUSE

Series	Number of Plants	Borax ($\text{Na}_2\text{B}_4\text{O}_{10} \cdot 10 \text{ H}_2\text{O}$) (Pounds per Acre)	Average Weight of Head (Grams)	Average Weight of Plant (Grams)
A	10	None	196.1	641.4
B	10	2.5	278.7	700.6
C	10	5.0	292.8	720.4
D	10	7.5	284.4	784.2
E	10	15.0	302.0	785.3
F	10	25.0	303.3	844.9

Results of Greenhouse Experiment:—When the plants reached maturity all heads in series A (no borax) showed severe browning and were bitter. In series B (2.5 pounds of borax to the acre) four plants showed slight internal discoloration, but no surface browning; and in series C (5 pounds of borax to the acre) two plants showed minute spots in the interior of the apical portion of the stem. No browning or other discoloration appeared in any of the plants in series D, E and F.

The discoloration of the curd appeared at various stages of maturity and increased with the growth of the head. A longitudinal section through the stem and curd of severely browned heads showed clearly transverse splitting of the pith and this was followed by vertical splitting and eventually the stem became hollow.

The effect of the borax treatment on the weight of plant and weight of head is shown in Table I. The data indicate that, in general, weight of plant increased as the quantity of borax increased, up to 25 pounds to the acre. The average weight of head increased with added increments of borax with one exception (series D) and in this case one dwarfed plant accounts for this apparent inconsistency.

Application of borax to the soil had considerable effect on the root system of the plants. Where borax was supplied, the roots permeated the entire soil mass; whereas in the absence of borax the plants were shallow rooted. It is possible that the poorer growth of roots in the soil to which no borax was applied resulted from injury to the root tips as reported by Eltinge (2) in the case of corn plants grown in a boron-deficient nutrient solution.

FIELD EXPERIMENTS IN 1936

Results of field experiments carried on in 1935 and of the greenhouse experiments conducted during the winter season of 1935-36 indicated clearly that borax was effective in controlling cauliflower browning. The main object of the field experiments conducted in 1936 was to determine the quantity of borax required to control browning on soils of different types when the application was made broadcast with the fertilizer. For this purpose experiments were started on three major types of soil used for cauliflower in the region. These soils are Lackawanna silt loam, Culvers silt loam, and Barbour silt loam, high-bottom phase.

The area selected on the Lackawanna silt loam produced a crop of cauliflower in 1935 and had received 2 tons of hydrated lime and 2 tons

of a 4-8-7 fertilizer to the acre. At least 75 per cent of the cauliflower grown on this land in 1935 was so badly browned that it was unmarketable. Prior to 1935 this area had been in pasture for 25 years. Since the soil was very acid in the spring of 1936, 2 tons of hydrated lime was applied on May 15 and this brought the reaction up to pH 6.0 to 6.6 in the surface 3 inches.

To the area of Culvers silt-loam soil used hydrated lime was applied at the rate of 1 ton to the acre in the fall of 1935 to a poverty-grass sod. This was plowed under. In the spring of 1936 the reaction varied from pH 5.2 to 6.2. An application of 2 tons of lime to the acre was broadcast and harrowed in, prior to planting the crop.

The experiment on the Barbour soil was of little value because of drought, therefore, no description is given of the treatments applied to this soil.

On each soil type four treatments were given as follows: (a) no borax, (b) 5 pounds, (c) 10 pounds, and (d) 25 pounds of borax to the acre. All plots received an application of 2 tons of 4-8-7 fertilizer to the acre made up of nitrate of soda, sulphate of ammonia, 16 per cent superphosphate and 58 per cent muriate of potash. The fertilizer ingredients were weighed out and thoroughly mixed and the necessary quantities of borax for the various rates of application were added to the mixture. The fertilizer was applied broadcast and was mixed with the surface soil by harrowing.

The plots on the Lackawanna soil were 18.75 by 24.25 feet. The plants were spaced 16 to 18 inches apart in the row with the rows 3 feet apart, giving an average of 75 plants to the plot. The plots on Culver soil were 12.5 x 20.5 feet and contained 45 plants to the plot. All treatments were in quintuplicate and well distributed.

When the plants reached market maturity the head was cut off below the lowest leaf and the entire mass of foliage and curd was weighed. The stems and heads were examined for symptoms of browning.

RESULTS

The effect of the borax treatments on the percentage of first and second grade heads and on the percentage of heads showing browning is shown in Table II.

TABLE II—EFFECT OF BORAX ON GRADE AND ON BROWNING OF CAULIFLOWER ON TWO TYPES OF SOIL

Borax per Acre (Pounds)	Lackawanna Silt Loam			Culvers Silt Loam		
	Grade 1 (Per Cent)	Grade 2 (Per Cent)	Browning (Per Cent)	Grade 1 (Per Cent)	Grade 2 (Per Cent)	Browning (Per Cent)
0	43.7	25.5	24.4	21.6	5.2	49.3
5	56.0	30.6	1.3	53.0	18.3	0.0
10	58.1	32.2	0.5	50.2	21.0	0.0
25	55.2	33.4	0.0	60.3	15.2	0.0

On the Culvers silt loam soil all plants on the borax-treated plots were free from both internal and surface browning, while 49 per cent

of the plants on the plots that had no borax showed browning. On the Lackawanna soil no surface browning developed on any plant in the borax-treated plots. However, 5 plants on the plots given 5 pounds of borax and two plants given 10 pounds of borax to the acre showed slight internal discoloration. No evidence of either internal or surface browning was found on the plots that received 25 pounds of borax to the acre.

The percentage of marketable heads (firsts and seconds) produced on the borax-treated plots was significantly higher than on the no-borax plots. The difference in percentage of marketable heads and in percentage of heads showing browning between the various borax treatments is not significant.

In spite of the fact that heavy applications of lime were made, whip-tail was present on the experimental plots. It should be noted, however, that the soil below the surface 3 or 4 inches had a reaction of about pH 5. Borax had no significant effect on the prevalence of whip-tail.

In addition to the experiments previously discussed, a number of tests were made on other farms in the region and observations were made on a large number of farms where borax was included in the commercial fertilizer used. In all cases where the application was at the rate of 6 pounds or more of borax to the acre, browning was controlled, except where the borax was mixed with hydrated lime. A large part of the fertilizer used for cauliflower in Delaware County contained some added borax, but in some cases the quantity was not sufficient to give good control of browning.

Results of tests made on three farms in 1936 indicate that borax is effective in controlling browning even when applied late in the season—after the heads began to form. On one field of two acres of cauliflower borax was applied at the rate of 6 pounds to the acre in the fertilizer, except on one small area in the center of the block. On the small block containing 350 plants, borax in solution was applied at the rate of 18 pounds to the acre to some of the rows on August 19 at the time that some of the plants in the block showed evidence of boron deficiency. The solution was sprinkled on the soil on both sides of the row on several rows. Four rows were left as check between treatments. At the time the solution was applied an occasional head was forming. Five weeks later plants in the check rows showed severe browning, but none of the treated plants were browned. Similar results were obtained by applying dust in the form of borax and boric acid, using the same rate of application of boron as was used in solution. Where sufficient borax is applied in the fertilizer, later applications should not be necessary.

Rutabagas are grown in many fields in Delaware County and in those in which cauliflower browning develops, rutabagas show an internal discoloration or browning. This trouble probably is the same as that described by several workers, including McLeod (3), as brown heart in turnips and by O'Brien and Dennis (4) and others as "raan" in swedes or rutabagas. Observations made on rutabagas in Delaware County, New York indicated that the browning of rutabagas was controlled by applications of 6 or more pounds of borax to the acre. These

observations are in line with experimental results reported by workers in Canada and in other countries.

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Effect of Source of Nitrate Nitrogen and a Mixture of Minor Plant Nutrients on the Growth of Cabbage Plants in Pots¹

By W. D. KIMBROUGH, *Louisiana Agricultural Experiment Station, Baton Rouge, La.*

INTRODUCTION

INFORMATION concerning the importance of many elements once thought to be unessential to plant life and growth has been accumulating rapidly for the past few years. In some cases the application of some elements known to be essential, other than those ordinarily found in fertilizers, has proved very advantageous. No review of literature will be attempted in this paper as this may be found in a paper by Willis.² Attention is directed to the practical importance of the application of some of the elements that have been considered unimportant. The application of zinc to rosetted pecan trees and tung trees affected with bronzing seems to be very beneficial. The stimulating effect of copper in Bordeaux mixture is taken into consideration in the recommendations for spraying Irish potatoes in New York State. The application of copper to muck lands in Florida has given marked increases in crop yields. The application of magnesium is considered beneficial to crops in many places along the Atlantic seaboard. This goes to show that progress in plant nutrition is being made and indicates that as well as being of academic interest the knowledge of the essential nature of some of the elements needed in minor amounts already has a practical application.

An observation was largely responsible for the start of the work reported in this paper. Some results of an experiment on the effect of the sources of nitrogen on the growth of cabbage in pots, in 1927, showed considerable difference between commercial nitrate of soda and nitrate of lime. Plants grown with nitrate of lime as the source of nitrogen seemed to have some physiological disorder. It was not believed that differences in the cations explained the differences obtained. The following year (1928) chemically pure nitrate of soda was used as a source of nitrogen as well as commercial nitrate of soda and nitrate of lime, for cabbage plants grown in pots. Results obtained indicated that differences in growth of cabbage where different sources of nitrate were used might be due to impurities in the commercial nitrate of soda. A pot experiment was set up in 1929 to definitely determine whether the source of nitrate nitrogen would influence the physiological well being of cabbage plants and, if so, whether a mixture of elements not commonly applied as fertilizer would have any influence on the plants.

¹This work was done at the Alabama Agricultural Experiment Station.

²The Minor Elements, L. G. Willis, Soil Chemist, North Carolina Agricultural Experiment Station, Raleigh, North Carolina.

PROCEDURE

Jersey Wakefield cabbage was grown in the greenhouse from seed in 2 gallon glazed pots containing 10 kilograms of sifted Norfolk sand obtained from the experiment station farm. Only one plant was allowed to grow in a pot. The same amounts of nitrogen, superphosphate, and potash were applied to each pot. All of the superphosphate, one-fourth of the nitrate and one-third of the muriate of potash were applied before planting. The rest of the nitrate and muriate were applied in solution at two later dates. The rates and times of application of fertilizer used had given best results in earlier pot experiments with cabbage. The mixture of small amounts of elements was applied before planting. For convenience this mixture will be called an A to Z mixture when referred to later in this paper.

The rates of fertilizer materials applied were as follows: nitrate of soda, or equivalent, 1 ton per acre, superphosphate 1 ton per acre, and muriate of potash 300 pounds per acre. Compounds making up the A to Z mixture were applied at the following rates: Boric acid 5 pounds per acre; MnSO_4 20 pounds per acre; CuSO_4 20 pounds per acre; BaCl_2 10 pounds per acre; KI 5 pounds per acre. About a half gram of metallic zinc was added to each pot receiving the A to Z mixture. The various treatments given and the number of pots per treatment were:

Chilean nitrate of soda.....	12 pots
Chilean nitrate of soda plus A to Z mixture.....	6 pots
C. P. nitrate of soda.....	12 pots
C. P. nitrate of soda plus A to Z mixture.....	6 pots
Champion brand Chilean nitrate of soda.....	12 pots
Champion brand Chilean nitrate of soda plus A to Z mixture.....	5 pots
Nitrate of lime (commercial).....	12 pots
Nitrate of lime (commercial) plus A to Z mixture.....	6 pots
Synthetic nitrate of soda.....	14 pots
Synthetic nitrate of soda plus A to Z mixture.....	6 pots

The plants were watered with tap water which was applied often enough to prevent injury from lack of water. Six additional plants, which had received C. P. nitrate of soda as a source of nitrogen, were water with distilled water to compare them with similar plants watered with tap water.

Seeds were planted October 14, 1929, and the plants were harvested February 15, 1930. Notes were made at intervals during the period of growth on the condition of the plants. Pictures were taken February 2 to show differences due to fertilizer treatment.

RESULTS

All plants grew well for a time with no apparent consistent differences due to treatment given, with the exception of plants watered with distilled water, which did not grow quite so well. This held true until head formation started which was about the first of January. From this time on differences began to appear. These differences appeared in three forms described as follows:

(a) There was a spotting of the leaves of some plants. The spots appeared first as light specks with outgrowths on the underside of the leaves. These increased in size and with age seemed to cork over. The outgrowth somewhat resembled small warts. No spots appeared on the basal parts of leaves crowded by the next leaf below. None of these spots appeared on any plant where the A to Z mixture had been



FIG. 1. Leaf at left from plant receiving C. P. sodium nitrate. Leaf at right from plant receiving similar treatment with the addition of an A to Z mixture.



FIG. 2. Plant which received C. P. nitrate of soda, which shows marginal leaf injury which destroyed possibilities for head formation.

FIG. 3. Plant which received C. P. nitrate of soda plus A to Z mixture, showing normal head formation.

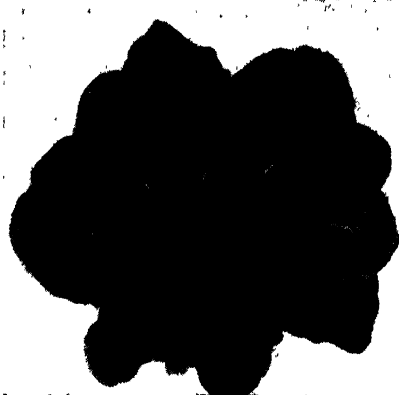


FIG. 4. Plant which received Synthetic nitrate of soda, which shows marginal leaf injury and failure to head.



FIG. 5. Plant which received Synthetic nitrate of soda plus A to Z mixture, showing normal head formation.

applied. Spots were first found January 29th on plants which had received the two Chilean brands of nitrate of soda. The spotting was never severe in any case where these two sources of nitrate were used. All other plants not receiving the A to Z mixture showed spotting on January 9th. A leaf with the spots and one without them is shown in Fig. 1.

(b) Another, the most important, form of injury appeared as a withering of the margins of the inner leaves, especially those that were starting to form heads or were parts of small heads. The withered portion soon became dry. A few heads showed but little injury on the

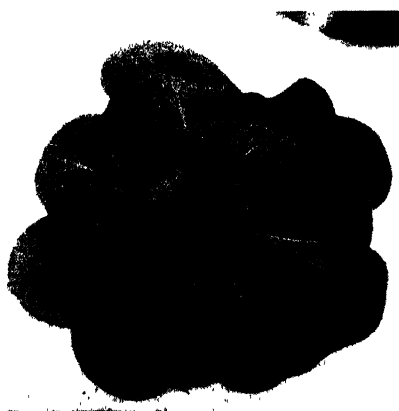


FIG. 6. Plant which received nitrate of lime, showing marginal leaf injury, which injured the head that started.



FIG. 7. Plant receiving nitrate of lime plus an A to Z mixture, showing that normal head formation has started.

outside when harvested, but when torn apart and examined, marginal injury was found on nearly every leaf. This type of injury was not found on any plant which received the A to Z mixture. One plant each of those which received the Chilean brands of nitrate of soda showed very slight injury which did not extend into the head. This injury was present in severe form on several plants of each of the other treatments. It is illustrated in Figs. 2, 4, and 6, and is to be compared with uninjured plants in Figs. 3, 5, 7, and 8.



FIG. 8. Plant which received Chilean nitrate of soda, showing normal head.



FIG. 9. Plant which received C. P. nitrate of soda and was watered with distilled water, showing lack of head formation.

(c) Another effect of fertilizer was the influence on head formation. With some treatments there seemed to be a tendency not to form heads. This was especially true where C. P. nitrate of soda was used and the plants watered with distilled water. Instead of forming a head the leaves seemed to turn out. This is illustrated in Fig. 9. Several plants in other treatments showed a similar tendency. The A to Z mixture seemed to increase the tendency toward head formation.

Records were taken at harvest time of the green weight of the above ground part of the plant, the weight of head with injured leaves, if any were present, removed, and the degree of spotting and marginal leaf injury. Data obtained are given in Table I.

The data in Table I and the pictures clearly show differences in the plants due to the source of nitrate nitrogen. This is especially true concerning head formation. When certain sources were used a physiological⁸ breakdown occurred in many cases and possibilities for forming a normal head were removed. This did not occur when certain materials not usually applied in fertilizer were added. That there was practically no injury where certain sources of nitrate were used

⁸Injured portions of leaves were examined by a plant pathologist for disease organisms. None were found, however, and the injury was pronounced physiological. Appreciation is expressed to Dr. J. L. Seal for examining the tissues.

TABLE I.—EFFECT OF SOURCE OF NITRATE AND A TO Z MIXTURE ON CABBAGE GROWN IN POTS

Treatment*	Number of Plants	Number of Heads	Average Green Weight of Tops (Grams)	Average Weight of Heads (Grams)	Number of Cabbage Plants with Spotted Leaves				Number of Cabbage Plants with Leaf Marginal Injury		
					Trace	Slight	Medium	Bad	Slight	Medium	Bad
NaNO ₃ C. P. distilled water	6	0	309	0	0	2	3	1	4	0	0
Champion brand	12	10	598	153	3	2	1	0	1	0	0
Champion plus A to Z	5	5	579	197	0	0	0	0	0	0	0
NaNO ₃ (C. P.)	12	3	489	18	2	1	5	4	6	3	3
NaNO ₃ (C. P.) plus A to Z	6	6	524	166	0	0	0	0	0	0	0
Old Chilean	12	10	565	168	3	2	0	0	1	0	0
Old Chilean plus A to Z	6	6	513	176	0	0	0	0	0	0	0
Ca (NO ₃) ₂	12	2	438	22	1	4	4	3	3	1	2
Ca (NO ₃) ₂ plus A to Z	6	6	459	123	0	0	0	0	0	0	0
Synthetic	14	2	580	8	1	2	7	4	6	3	4
Synthetic plus A to Z	6	5	481	139	0	0	0	0	0	0	0

*Superphosphate (16 per cent) was applied at the rate of 1 ton per acre.
 Muriate of potash was applied at the rate of 300 pounds per acre.

strongly indicates that these contained some other element or elements beneficial to cabbage especially in the formation of heads. The element or elements applied in the A to Z mixture that proved beneficial has not as yet been determined.

The plants that were watered with distilled water further emphasized the lack of something necessary for normal growth. The inability of plants to make a successful start toward head formation may mean that this is influenced by certain elements. This is further indicated by the proportion of heads obtained where the A to Z mixture was used. Severe marginal injury in the case of some treatments so injured a few heads that had started that there were no heads present when records were taken. Many plants apparently did not start the formation of heads, and in these cases marginal injury to the leaves either did not appear or was rather slight.

DISCUSSION

As an ordinary Norfolk sand and tap water were used in this experiment, similar results should be obtained in the field with similar soil. As the roots of plants grown in the field would not be as restricted as those grown in pots, several years might be necessary for results to be duplicated even with the very poor soil used. On fertile mineral soils there is little or no evidence that the minor elements are needed.

The results obtained with cabbage grown in pots show that the so-called natural nitrate of soda does contain something other than nitrogen, which synthetic sources at present do not contain, that may under certain conditions be beneficial. The quantity of these impurities was not excessive as shown by the fact that the physiological disturbances were present to a slight extent where Chilean nitrate sources of nitrogen were used and the A to Z mixture was beneficial when used with them. Important impurities could be added to synthetic sources of nitrogen, if they are found to be sufficiently important.

Some Factors Associated with Puffy-Headed Cabbage

By JULIAN C. MILLER, *Louisiana State University, Baton Rouge, La.*

THE loss resulting from puffy cabbage is a serious factor throughout the country, especially with the early crop. The greater losses occur in trucking areas of the South Atlantic and Gulf States when the crop is maturing during midwinter or very early spring. Puffy heads, if not entirely a loss, cause many disappointments. The grower may think he has a good cabbage crop but when the crop is cut and ready for shipment, the Federal inspector rejects it as No. 1 cabbage. If for any reason it is shipped to the market and escaped notice until the housewife discovers that she has purchased a poor cabbage, the result may be that cabbage is not on her next market order. Sometimes the grower realizes the condition of his crop and tries to sell it as green or immature cabbage. Experience has taught him that unless the crop is sold as such, he may not realize paying returns.

For studying the problem, plantings were made at monthly intervals from July to April. It was found that those plantings which matured during January and February when the mean temperature was 52.3 degrees F showed the highest number of puffy heads. The plantings showing the smaller percentage of puffy heads were those which matured during April and May when the mean temperature was 68.5 degrees F. None of the commercial varieties yet tested has been found to be immune to this character; however, some are far more resistant than others. To further illustrate this, some data which were recorded from harvestings made during the last of January and the first of February are presented in Table I.

TABLE I—DATA FROM MIDWINTER HARVEST SHOWING NUMBER OF PLANTS OF SIX VARIETIES WHICH PRODUCED FIRM HEADS AND THE NUMBER WHICH PRODUCED PUFFY HEADS (3-YEAR AVERAGE)

Variety	Number Heads		Per Cent Puffy
	Firm	Puffy	
All-Head-Early	232	146	38.6
Succession	7440	2820	27.5
Danish Bald Head	540	223	29.2
Copenhagen Market	680	236	25.8
Louisiana Copenhagen	832	89	9.7
Charleston Wakefield	496	114	18.7

The data presented show the number of firm and puffy heads and the per cent of puffy heads taken from some of the leading varieties. It is observed further that the hardy variety, Charleston Wakefield, had a significantly smaller percentage of puffy heads than the All-Head-Early. Also, that the Louisiana Copenhagen, which has been selected for resistance to this character, was the best of the varieties tested, being significantly better than the standard Copenhagen Market.

It requires considerable study and observation to be able to recognize the various types of puffy heads or head seeders. Each of the puffy heads is a potential seeder and the physiological metabolism of the plant

is in a delicate balance between seeding and heading. Should the weather remain cool, 50 to 60 degrees F for a period of 30 to 60 days during the heading stage, seedstalks usually emerge. On the other hand, should the weather turn warm, 70 to 80 degrees F for a similar period at this time, seeding is depressed. In most cases the puffy heads can be identified by one of the following characteristics: head formation upon a high stem; softness of the head; a hollow sound which results when

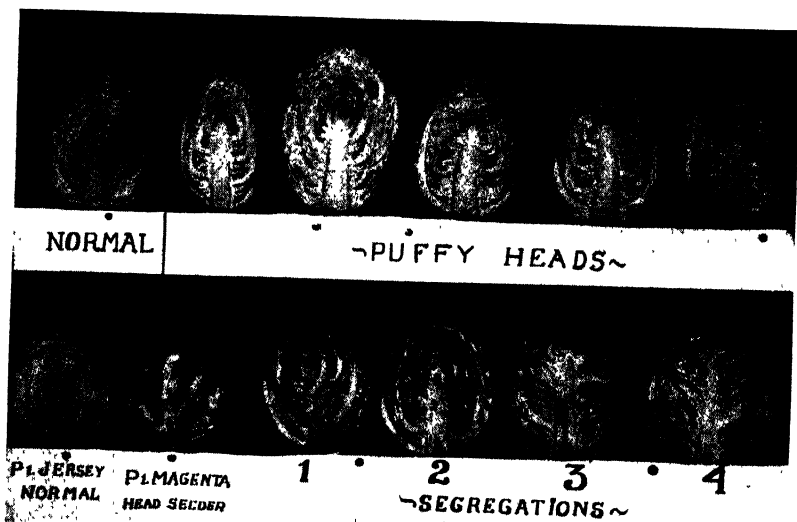


FIG. 1. Top Row: From left to right, Plant 1 represents the ideal type of Charleston Wakefield. The five heads to its right represent types of puffy heads of this same variety.

Lower Row: From left to right, Head "P1 Jersey Normal" is a pure strain of Charleston Wakefield. Head "P2 Magenta Head Seeder" is pure strain of Jersey head seeder type. Plants 1 to 4 are segregations of the Jersey and head seeder cross.

the head is thumped; and in the later stages of heading, by the irregularity of the characteristic head shape of the variety which probably results from the elongation of the core. The final test when definite counts and complete examinations are made is given by cutting a longitudinal cross section.

To illustrate these points further, it is well to study the top row of heads in Fig. 1. The first cross section at the left illustrates the interior character of a head that approaches an ideal type of Charleston Wakefield. The other five heads to the right represent types of puffy heads of the same variety grown under identical conditions. It can be further noted that as a result of the elongated core, the lower head leaves grow from the core at an angle of as much as 90 degrees and an air pocket usually results at the curve of the leaf as it makes its upward turn toward the folding position. Seedstalk buds have been initiated in the axil of the leaves, as can be seen from further observation of Fig. 1.

The internal characters of puffy heads of other varieties, such as the Copenhagen Market, are about the same as those described for the Charleston Wakefield.

Realizing that both environment and heredity have a role in the problem of puffy cabbage, two widely different selected strains were crossed for study. Parent 1 was an inbred line of five generations which had been selected for compactness of head. Parent 2 was selected for the head seeding character over a similar period of time and is closely associated with puffiness. These two strains are shown in the lower row of Fig. 1 from left to right, heads 1 and 2, marked "P1. Jersey Normal" and "P2. Magenta Head Seeder". The types of F_1 segregations resulting from this cross are shown in the heads marked from 1 to 4. It is noted that the parental types as well as intermediate types resulted in the segregations. No interpretation of F_1 and F_2 data will be presented in this paper. As has already been inferred, however, there was incomplete dominance of the internal head characters of these two strains in the F_1 generation. It is hoped that the brief discussion of the above cross and segregations will serve to illustrate how puffy head and annual seeding types result.

From the study and data obtained so far, it would seem that the cause of puffy heads is a heterozygous condition of the particular strain, which is brought into a definite expression by growing the plants during a season of relatively low temperature. To improve this situation, strains which are resistant to this character will have to be bred. This can be done, as is shown in Table I. The Louisiana Copenhagen has been selected for resistance to the puffy character and for a compact head. It shows 50 per cent less puffy heads than the Charleston Wakefield, which was the next best variety. The Charleston Wakefield is one of the hardiest midwinter varieties and in general is more resistant to cold and to premature seeding than the Copenhagen Market.

Physiological Factors Associated with the Fruiting of the Bush Lima Bean

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RECENT investigations (1, 2) have shown that differences in stomatal behavior, chlorophyll content, osmotic pressure and carbohydrate content of the leaves, explain partially the wide differences in the yielding ability of the Henderson (small seeded) and the Fordhook (large seeded) Bush Lima bean when grown under hot dry conditions. The Henderson had more open stomata, higher chlorophyll and carbohydrate content, higher osmotic pressure of leaf sap and produced higher yields than the Fordhook. The pollen of the Henderson usually germinated the same day of anthesis while that of the Fordhook usually germinated 1 or 2 days later. These physiological differences indicated that the Henderson possesses a greater photo synthetic capacity than the Fordhook.

To obtain additional information on the differential response of the large and small seeded sorts, studies were made during 1936 of the yields, stomatal behavior, stomata size and number, the chlorophyll content of leaves, leaf area, leaf thickness and length of palisade cells of Henderson and Fordhook plants grown in the open and in the shade.

Two plantings were made at Clemson June 24 and one at Highlands July 2 (50 miles northwest of Clemson in the mountains of North Carolina where the temperature is lower and humidity higher than at Clemson) in 50 foot single row plots replicated five times. After the seed had germinated a 4-8-4 fertilizer mixture was applied in furrows 3 inches from either side of the plants at the rate of 600 pounds per acre. The seedlings were thinned to 12 inches apart in rows 2½ feet apart.

Yield data in terms of number and weight of mature green pods per plant were secured.

Stomatal activity was determined by Molisch's infiltration method (4) as described in a previous report (1). The accuracy of the method was confirmed by a modification of Lloyd's (5) method in which the epidermis is removed from the leaf and immediately submerged in absolute alcohol to fix the stomata for observation under a microscope. It was found that absolute alcohol was a satisfactory penetrating agent for bean leaves and that the relative number and degree or size of stomatal opening could be determined by the speed and degree of penetration of the alcohol into the intercellular spaces. Numbers from 1 to 100 were used as a basis for recording the relative stomatal opening. This report is based on observations made on three mature upper leaves per plant and five plants per plot examined at hourly intervals between 7 a. m. and 6 p. m. at least 3 times a week during the entire fruiting period.

The chlorophyll content of the upper mature leaves was determined at weekly intervals during the first 3 weeks of fruiting. Samples were taken at 8:00 a. m. and 5:00 p. m. by means of a ½-inch cork borer. Six ½-inch discs were removed from each of two upper mature leaves

per plant of five plants per plot to obtain a 2 gram sample. Analyses were made by methods previously described (1).

Leaf thickness and palisade cell length were determined by the use of a screw micrometer from slides of leaves fixed in Allen's modified Bouin's solution cut by the paraffin method and stained in Fleming's Triple stain.

The data on the mean total yields, chlorophyll content and stomatal behavior of the two varieties grown (a) at Clemson in the open and (b) at Clemson under a Sun-Ray-Tex cloth house-shade and (c) at Highlands in the open are presented in Table I.

TABLE I—VARIETAL DIFFERENCES IN YIELD, CHLOROPHYLL CONTENT AND STOMATAL OPENING OF PLANTS OF HENDERSON (SMALL SEED) AND FORDHOOK (LARGE SEED) BUSH LIMA BEANS GROWN UNDER VARIABLE CONDITIONS—1936

Variety	Mean Yield Weight Pods per Plant (Grams)	Mean Yield Number Pods per Plant	Mean Chlorophyll Con- tent Milligrams per 100 Discs†	Mean Stomatal Opening Per Cent at 2:00 P. M.	Mean Temperature (T) and Humid- ity (H) at 5:00 P. M.	
					T	H

<i>Clemson— Not Shaded</i>						
Henderson	71.0	19.5	2.547	94.0		
Fordhook	59.6	6.6	2.174	64.5	81	66
Difference (H minus F)	*12.0 ± 1.67	*13.0 ± 0.49	*0.352 ± 0.013	*29.5 ± 4.26		
<i>Clemson -Shaded</i>						
Henderson	128.1	33.6	2.589	99.8		
Fordhook	142.1	14.06	2.397	89.6	82	71
Difference (H minus F)	*17.7 ± 5.30	*19.7 ± 0.87	*0.192 ± 0.024	*10.2 ± 1.08		
<i>Highlands Not Shaded</i>						
Henderson	189.2	41.8	3.070	97.3		
Fordhook	228.6	17.6	2.506	94.7	68	79
(H minus F)	*35.5 ± 9.31	*24.2 ± 0.67	*0.564 ± 0.031	* 2.7 ± 1.10		

*Differences are considered significant ± standard error

†One-half inch discs.

The data show that within each variety the yields, chlorophyll content and stomatal activity are significantly greater at Highlands in the open and at Clemson in the shade than at Clemson in the open.

At Clemson in the open the Henderson produced greater yields than the Fordhook. However, at both Clemson in the shade and at Highlands in the open where the humidity was high, the yields in weight pods per plant of the Fordhook are significantly greater than those of the Henderson.

In all cases the Henderson had greater chlorophyll content than the Fordhook. At Clemson in the open and in shade the differences were much greater in the afternoon than in the morning. At Highlands in the open the differences were slightly greater in the afternoon than in the morning.

At Clemson both in the shade and in the open the stomata of the Henderson were more open than those of the Fordhook. The differences were greater in the open, than in the shade, and were greater in the afternoon, than in the morning. Apparently, the Fordhook with its lesser chlorophyll content and thinner leaves in the open benefited to a greater extent from shade than did the Henderson. This is manifested by the greater increase in chlorophyll, stomatal activity and yield over Fordhook when grown in the shade.

The data on thickness of the leaves and length of palisade cells are presented in Table II. The data show that a Clemson in the open the Henderson possessed thicker leaves and greater length of palisade

TABLE II—THE VARIETAL DIFFERENCES IN LEAF THICKNESS, PALISADE CELL LENGTH AND STOMATAL OPENING OF THE HENDERSON (SMALL SEEDED) AND FORDHOOK (LARGE SEEDED) BUSH LIMA BEAN GROWN UNDER VARIABLE CONDITIONS—1936

Variety	Mean Leaf Thickness (Microns)	Mean Length Palisade Cells (Microns)	Mean Stomatal Opening 8:00 A.M. (Per Cent)	Mean Stomatal Opening 2:00 P.M. (Per Cent)	Mean Stomatal Opening 5:00 P.M. (Per Cent)
<i>Clemson—Not Shaded</i>					
Henderson	234.0	111.9	92.4	94.0	89.0
Fordhook	207.0	100.8	86.4	65.0	46.4
Difference (H minus F)	$*27 \pm 3.64$	$*11.1 \pm 1.61$	$*6.0 \pm 1.88$	$*29.0 \pm 4.33$	$*42.6 \pm 4.47$
<i>Clemson—Shaded</i>					
Henderson	195.82	98.4	97.8	99.8	69.4
Fordhook	194.70	92.7	93.7	89.6	26.6
Difference (H minus F)	1.12 ± 3.93	5.7 ± 2.89	$*4.12 \pm 1.44$	$*10.4 \pm 1.08$	$*42.8 \pm 3.43$
<i>Highlands—Not Shaded</i>					
Henderson	200.0	99.4	96.4	97.3	63.1
Fordhook	235.0	102.6	79.4	94.7	67.1
Difference (H minus F)	-35 ± 3.99	-3.2 ± 3.11	$*12.9 \pm 3.5$	2.6 ± 3.56	-4.0 ± 3.50

*Differences are considered significant $\pm$ standard error.

cells than did the Fordhook. However, at Highlands in the open the Fordhook possessed thicker leaves than the Henderson, with no differences in length of palisade cells.

At Clemson in shade both varieties had approximately the same leaf thickness and length of palisade cells.

These data indicate that the production of thickness of leaves, greater chlorophyll contents, longer palisade cells and more open stomata of the Henderson combine to reduce the deleterious influence of intense sunlight, high temperature and low humidity and to promote greater stomatal opening and greater photosynthetic capacity which explains, partially at least the greater adaptability of the Henderson to hot dry conditions than that of the Fordhook.

Since in all treatments the chlorophyll content of the Henderson is greater than that of the Fordhook, it seems to be one of the chief factors responsible for the wider adaptability of the Henderson.

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The Effect of Controlled Photoperiod on the Production of Seed Stalks in Eight Varieties of Spinach

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THE evidence that has already demonstrated the importance of day length as a factor in the production and elongation of seed stalks in spinach is based largely on work with one or two varieties, or on work conducted under conditions of normally changing length of day. The present report covers the results of 1 year's studies with eight of the most important varieties and types of spinach, grown under the same temperature conditions but at constant day lengths of 8, 10, 12, and 14 hours, and the normal day length which varied from 13.7 to 14.92 hours.

MATERIALS AND METHODS

The eight varieties listed in Table II constitute the important varieties grown in the United States and the strains used were typical of the variety and were the most uniform stocks submitted for use in the vegetable variety standardization project of the Bureau of Plant Industry, United States Department of Agriculture and cooperating State experiment stations.

Seed was sown in flats in the greenhouse on April 18 and the seedlings were transplanted into the experimental boxes on April 28, 1936. The boxes were 10 inches deep, 10 inches wide, 36 inches long and filled with composted soil. Two rows of 10 plants each were set in each box, the rows being approximately 6 inches apart and the plants 3½ inches apart in the row. Because of the limited space available only 10 plants of each variety could be grown in each length of day treatment. The length of daylight exposure was regulated by running the

TABLE I—THE RANGE AND AVERAGE IN WEEKLY AIR TEMPERATURES AT ARLINGTON EXPERIMENTAL FARM, ROSSLYN, VIRGINIA, DURING THE SPINACH GROWING SEASON OF 1936

Week Ending	Minimum		Maximum		Mean	
	Range	Average	Range	Average	Range	Average
May 4	40-60	54	68-86	81	59-71	67
11	47-60	52	65-89	77	61-73	65
18	35-61	50	58-89	77	53-75	63
25	48-71	55	71-89	78	61-76	66
June 1	43-63	54	68-86	77	56-73	65
8	53-72	63	75-95	84	68-83	73
15	63-67	65	78-90	83	71-77	74
22	56-74	66	76-90	86	72-80	76
29	55-71	60	61-93	81	61-82	70
July 6	65-71	68	69-91	85	67-80	76
13	63-75	70	83-107	97	79-89	83
20	62-75	69	87-96	92	77-85	80

TABLE II.—NUMBER OF DAYS FROM PLANTING REQUIRED FOR APPEARANCE OF FIRST SEEDER AND FOR 100 PER CENT SEEDERS IN EIGHT VARIETIES OF SPINACH GROWN AT DIFFERENT LENGTHS OF DAY

Variety	8-hour Day		10-hour Day		12-hour Day		14-hour Day		Check	
	First Seeder (Days)	All Seeding (Days)	First Seeder (Days)	All Seeding (Days)	First Seeder (Days)	All Seeding (Days)	First Seeder (Days)	All Seeding (Days)	First Seeder (Days)	All Seeding (Days)
Virginia Savoy	53	?	53	?	24	53	21*	27	21*	27
Bloomsdale Savoy	—	—	—	—	53	—	30	49	27	49
Long Standing Bloomsdale	—	—	—	—	—	—	41	63	41	63
Juliana	—	—	—	—	—	—	49	63	41	63
King of Denmark	—	—	—	—	—	—	53	?	41	69
Nobel	—	—	—	—	58	80	34	63	41	49
Hollandia	49	?	49	?	41	63	21	45	27	45
Viroflay	—	—	—	—	41	?	27	45	30	45

*Possibly a day or two earlier

— = No seed stalks produced in 80 days

? = Less than 100 per cent seed stalks in 80 days

boxes into and out of dark sheds according to schedules previously published in reports by Garner and Allard (2). The experimental treatment of the 8-, 10-, and 12-hour lots was started on April 28, the 14-hour lot on May 6, and the check or normal day lot remained outside during the duration of the experiment.

Air temperatures given in Table I were secured from official United States Weather Bureau instruments in regulation shelters located within 300 yards of the experimental area and are included to show the high temperatures that the plants encountered.

Observations of the number of plants with seed stalks were made on May 19, 22, 25, 28, June 1, 5, 8, 12, 16, 20, 25, 30, July 6 and 17. Any plant with visible elongation of the central or lateral axis was recorded as having a seed stalk. The results are given in Table II.

RESULTS

The seedlings grew rapidly and 21 days after transplanting the Virginia Savoy variety had reached a plant spread of $5\frac{1}{2}$ to 8 inches. The plants of all varieties were smaller in the 8- and 10-hour lots than in the other treatments and the 8-hour plants were slightly smaller than the 10-hour plants. The plants in these lots were also noticeably flatter in habit than in the longer day length lots.

A very good stand of plants was obtained but shortly after the first of June plants began dying from a disease which attacked the tender bud leaves, the crown and the root of the plant eventually causing wilting and death of the entire plant. The causal organism was identified by Dr. Charles Drechsler as *Pythium butleri* Subr. By the end of June this fungus had killed all the plants of Virginia Savoy, Juliana, Nobel, and Bloomsdale in the 10-hour lot and many plants in other varieties in other treatments. There was no evidence of resistance in any variety but the losses were greatest in the 8-, 10-, and 12-hour lots which were confined in the dark sheds during the night and part of the day. The humidity in the sheds was undoubtedly higher than on the outside and doubtless favored the spread of the organism in these lots. After the disease became evident the plants were watered as sparingly as possible but this measure did not stop the spread of the organism and by July 17 there was only one plant (Virginia Savoy) alive in the entire 8-hour lot, one (Hollandia) in the 10-hour lot, and seven in the 12-hour lot, (one of Virginia Savoy, two of Nobel, one of Bloomsdale, one of Viroflay, one of Long Standing Bloomsdale, and one of Hollandia). Since most of the plants in the 14-hour and check lots had produced seed stalks earlier than this date, their subsequent death occasioned no loss. It is doubtful if any of the plants in the 8-, 10- and 12-hour lots which did not produce seed stalks in the first 68 days would have done so if they could have grown another 68 days, but since the plants died this is merely conjecture.

The limitation of the light period to 8 and 10 hours daily prevented the formation of seed stalks in any plants of all varieties included in this experiment with the exception of the Virginia Savoy and Hollandia varieties (Table II). In the 8-hour lot, three out of seven plants of Virginia Savoy and four out of six plants of Hollandia were able

to produce a visible elongation of the lateral buds. The terminal axis did not elongate and none of the plants produced flowers by July 17. In the 10-hour lot, four out of five Virginia Savoy plants and three out of nine Hollandia plants also produced lateral branches but no elongation of the terminal axis.

A day length of 12 hours duration prevented the formation of seed stalks in the time available (70 to 80 days) on any plants in the Long Standing Bloomsdale, Juliana, and King of Denmark varieties. The largest percentage of seed stalks was 22 for Bloomsdale Savoy and 86 for Viroflay. All plants of Virginia Savoy, Nobel, and Hollandia produced seed stalks and the earlier "shooting" plants bloomed normally.

In the 14-hour and check or normal-day lots, all plants of all varieties produced seed stalks except the King of Denmark variety in the 14-hour lot which produced only 44 per cent seeders before the plants were killed by the disease.

The time required for the appearance of the first seeder or for 100 per cent seeders was decreased as the day length was increased from 8 to 10, to 12, to 14 hours. There was no significant difference between the results of the 14-hour treatment and the normal day treatment for the Virginia Savoy, Bloomsdale Savoy, Long Standing Bloomsdale, Hollandia and Viroflay varieties indicating that for these varieties, 14 hours of daylight was just as effective in the production of seed stalks as a longer period (up to 14.92 hours per day as the maximum). King of Denmark and possibly Juliana and Nobel, react to the longer days by an earlier date of first seeder or of 100 per cent seeders.

Considering the data from all the treatments the order of earliness in the formation of seed stalks is as follows: Virginia Savoy, Hollandia, Viroflay, Bloomsdale Savoy, Nobel, Long Standing Bloomsdale, Juliana, and King of Denmark.

DISCUSSION

It has already been shown (1) that when grown in Texas during the short days of winter Virginia Savoy produced seed stalks when the period of daylight was only 10.6 hours in length. In the present experiment there was some lengthening of the internodes of some of the plants subjected to 8 and 10 hour photoperiods but none of them were able to bloom even though high temperatures prevailed that would tend to accelerate seed-stalk formation and elongation. Unpublished data of J. E. Knott of Cornell University also show that Virginia Savoy will produce seed stalks with less than 10 hours possible daylight when grown during the winter at Ithaca, New York in the greenhouse. Knott's data also show that the length of day at which seed stalks are produced is also influenced by the temperature at which they are grown — seed stalks are produced with shorter length of day when temperatures are high than when they are low.

The Texas 1932 data show that Nobel spinach produced its first seed stalks when the days had reached only 11.5 hours in length and King of Denmark when the days had reached only 11.7 hours. The results with the King of Denmark variety would seem to be at variance with those of this experiment since King of Denmark was unable to produce

seed stalks at a constant day length of 14 hours. It is possible that the twilight-period light that is present in all normal day experiments may have some effect or value in plant growth. If this light of the twilight period (before sunrise and after sunset) is effective in the formation of seed stalks in spinach the results from crops grown under normal day lengths and from experiments of artificially shortened days are not exactly comparable. Then too, the reaction of varieties to photoperiod is influenced by temperature and they may respond differently to the various combinations of these factors. The experiment herein reported, however, demonstrates again that length of day is one of the major factors influencing seed stalk formation and elongation in spinach.

SUMMARY

Eight varieties of spinach were grown in the late spring and early summer at Rosslyn, Virginia, with 8, 10, 12 and 14 hours daily of normal light and the normal day length of possible sunlight which varied from 13.7 to 14.92 hours per day.

Of the strains used and under the conditions of this experiment only a portion of the plants of the Virginia Savoy and Hollandia varieties produced seed stalks at the 8- and 10-hour light exposures. None of the other varieties produced any seed stalks at these short light periods.

Twelve hours light duration was insufficient for the production of any seed stalks in the Long Standing Bloomsdale, Juliana, and King of Denmark varieties. Only a portion of the plants of the Bloomsdale Savoy and Viroflay varieties were able to produce seed stalks with 12 hours of light daily, but all of the plants of Virginia Savoy and Hollandia became seeders with 12 hours or more of light daily.

King of Denmark was the only variety that failed to produce 100 per cent of "seeders" with 14 hours of light daily, whereas all plants of all varieties became "seeders" under the normal day conditions.

An increase in length of day from 8 to 10, to 12, to 14 hours resulted in a decrease in the number of days required for the appearance of the first seeder, or of the number of days required for all plants to become seeders. Fourteen hours of daylight was just as effective as the longer normal day length in producing seed stalks in the Virginia Savoy, Bloomsdale Savoy, Long Standing Bloomsdale, Hollandia, and Viroflay varieties.

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A Separation of Certain Types of Response of Plants to Photoperiod¹

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IN the report of their second extensive studies of photoperiodism Garner and Allard (2) discuss and illustrate certain more or less typical effects of the light period on stem elongation, leaf growth and tuberization of various species of plants. Speaking of apogeotropism, or increase in stature, they say (p. 886) that "in a sense this is the fundamental phenomenon underlying the various other responses, including flowering and fruiting."

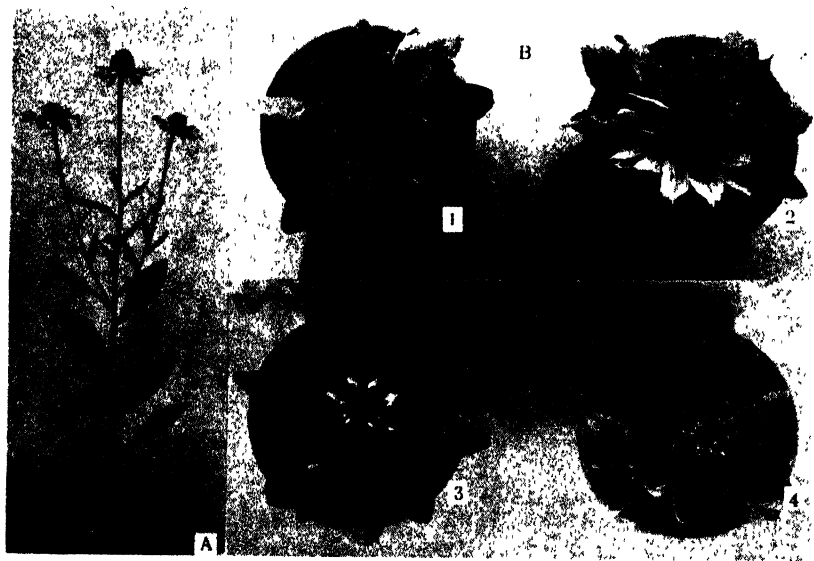


FIG. 1. Photoperiodism in Rudbeckia. A, Long-day plant. B, Short-day plants: 1, Vegetative rosette. 2, Rosette with one sessile flower. 3 and 4, Rosettes with "vegetative flowers".

While studying the characteristics of photoperiodism in certain plants, the writer obtained results which indicate that the influence of length of day on stem elongation and on reproduction are distinctly separable.

When, for example, Rudbeckia, was exposed during the seedling and early growth stages to a changing natural length of day of late winter and early spring months (10 to 13 hours) and then subjected to either a short (7 hour) or a long (14 to 15 hour) photoperiod, the results were as follows:

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Short day:—Plants either in rosette stage without flowers (Fig. 1, B-1), or rosette with flowers (Fig. 1, B-2), or rosette with “vegetative flowers” (Fig. 1, B-3 and 4).

Long day:—Normal plants—tall and producing flowers (Fig. 1, A).

The logical conclusion from these results would seem to be that the relatively short days (10+ hours) during the seedling stage inhibited stem elongation. But as the day length increased to 13 hours, in some of the plants (possibly those further advanced, since not all seeds germinated at the same time) floral primordia were initiated. Under the subsequent short-day exposure, which does not permit flowering in *Rudbeckia*, there were, therefore, three groups of plants: (a) those producing strictly vegetative rosettes, (b) those with rosette plus one large central flower and (c) rosette plants with vegetative flowers. The formation of flowers in all cases was the result of “photoperiodic induction” or photoperiodic “after-effect”. This induction of various intensities or dosages was brought about during the preliminary exposure to the natural length of day (10 to 13 hours). Plants subjected to a long day grew tall and flowered normally.

These experiments emphasize the fact that the effects of photoperiod on stem elongation and on flowering are two separate phenomena, though being affected by the same causal external factor. Hence it is possible, as in this experiment, to produce tall and rosette types of plants, both forming flowers normally. The writer proposes to designate the curtailment of stem elongation by a photoperiod as *photoperiodic inhibition*.

A feature of considerable significance is the production of “vegetative flowers” under certain combinations of light exposure. In the present case it was a photoperiod of 10 to 13 hours followed by one of 7 hours. A very large number, 33, of the *Rudbeckia* plants of our experiments produced such flowers under the final short-day exposure. They had but few abbreviated but normally colored petals, the rest being green like the sepals. The pistils and stamens were likewise “vegetative” to various degrees. These results are quite similar to those obtained with *Cosmos* by Biddulph (1).

The formation of partially developed flowers points to the fact that it takes a certain “dosage” or number of days to induce *fully* the initiation and growth of reproductive organs. A treatment short of this necessary minimum will be insufficient and will result in incomplete or partly vegetative flowers. This would seem to suggest that the mechanism of photoperiodism is not “trigger-like” in its action but that possibly a certain substance or substances are produced gradually, the quantitative accumulation of which results eventually in the development of reproductive organs. The possible existence of such a situation is encouraging indeed, for it suggests new methods of approach in our studies of the mechanism of photoperiodism.

Another illustration of the effects of length of day on stem elongation may be taken from the soybean, *var.* Biloxi (4). With a 7-hour exposure to light, growth in height of this plant begins to slow down early in comparison to growth of plants exposed to a long (14-hour) day. Photoperiodic inhibition may be noted in the short-day plants

already after the tenth day of the treatment and growth ceases almost completely in another 10 days as Table I shows.

TABLE I—RATE OF STEM ELONGATION OF SOYBEAN PLANTS, VAR. BILOXI

Age (Days)	Short-day Plants (Cm)	Long-day Plants (Cm)
2	4	4
6	10	10
12	17	18
20	20	25
27	21	33
33	21	42
40	21	48

Retardation in growth in this soybean takes place about the time the first primordia of flower buds are formed. This, however, does not seem to be in a cause and effect relationship with sexual reproduction of the plant.

That the almost complete check in growth of the stem is not the result of development of flowers and fruits, as is the case in the tomato (3), can be easily demonstrated by disbudding and defloration experiments. Photoperiodic inhibition here too is clearly a phenomenon that is separable from the effects of photoperiod on sexual reproduction.

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Quantitative Studies of Form and Size in Certain Vegetables¹

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CERTAIN characteristics of horticultural crops lend themselves readily to quantitative study, such as the weight or dimensions of plants or of their parts, and certain other characteristics likewise may be treated numerically by classification, as, for example, by determining the percentages of a population of plants which exhibit one or more clearly distinguished traits. In relatively few instances, however, have differences in such respects as shape or other less evidently defined characteristics been subjected to quantitative analysis.

Among the investigators who have attempted to describe the form of certain vegetables or fruits in numerical terms are Binkley (1) with onions, Edmond (6) with radishes, Carolus (3) and Krantz (8) with potatoes, Lindstrom (9, 10) with tomatoes, Pearson (14) with cabbage, Pelton (15) with beets, Pratt (16) with tomatoes, Shaw (17, 18, 19, 20) with apples, and Torres (22) and Work (23) with cabbage. In most cases, these investigators have used the ratios between axial and maximum transverse diameters as indices of form. In a few instances, notably those of Carolus, Edmond, and Shaw, an effort was made to find the effects of certain environmental influences on form in terms of the index used; in others, the form index was used to determine differences between varieties or between parental or filial groups of individuals. In certain studies, particularly those of Curtis and of Pelton, more than one transverse diameter was measured, and more than one index was considered; in the work of Curtis, three transverse diameters were measured, one equatorial and the other two quartile, or midway between the equatorial plane and the poles; Pelton used seven diameters in planes equally distant from each other and from the poles, the middle one being equatorial.

In the studies reported herewith, an attempt was made to ascertain the validity of indices of the types described, by determining their variability within and among varieties or strains as influenced by unknown soil and climatic influences and by different fertilizer treatments. Three types of plant organs were included in the study, namely heads of cabbage, fruits of tomato, and the so-called roots of beets.

PROCEDURE

Cabbage.—Head measurements were made on 16 varieties in the spring trials and on six of the same strains which were included also in the field, and the fertilizer treatments were the same. Seeds were manner of handling the plants, the planting distances in the flats and in a second trial in the fall of 1935. In both spring and fall trials, the

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sown thickly in drills about 2 inches apart in steamed compost soil contained in flats, and when seedlings were about $2\frac{1}{2}$ inches tall, they were transplanted into other flats at $1\frac{1}{2}$ inch distances. The plants in the spring trials were transplanted into the field on April 23, and those in the fall trials on July 23. Planting distances were 18 by 30 inches in both trials.

Sixty-seven plants of each strain were planted in the spring trials, each in a single plot consisting of one-half of a row. Two strains thus were included in each row, and some varieties were located at one end of the field and some at the other. In the fall trials, 25 plants were planted in single-row plots at random locations in the field. Several other strains known to be identical were included in both spring and fall trials, and were planted in plots among those of the strains on which the studies herein reported were made; these indicated that location in the field had no significant effect on size and form, although there was a little evidence that strains planted in the west end of the field in the spring trials were a little earlier than those in the east end.

Measurements in both cases included the weight and the axial and maximum transverse diameters of the trimmed head, the latter taken as the average of one transverse diameter measured at random and a second diameter at right angles to the first, both in the maximum cross section of the head. The dimensions were measured by means of wooden calipers with one fixed and one sliding jaw, both at right angles to a centimeter scale.

Tomatoes.—Two studies were carried out with tomatoes; one was a study of form and weight of fruits from duplicate plots of 16 strains of tomatoes in a variety trial, and the other was a comparison of the same characteristics, form and size, on duplicate plots of a fertilizer experiment, to ascertain the influence of the nutrient elements N, P, and K on these characteristics. Fruits were sampled on August 5 and 19 for the strain and on August 6 and 27 for the fertilizer studies. On the first date of sampling, the entire harvest, consisting of from 18 to 62 fruits from each plot, was taken for study in the strain comparison, and only single plots of six strains were included. Plots consisted of a single row of 10 plants which were set 4 feet apart in rows 5 feet apart. On the second date 30 fruits were taken at random from each of duplicate plots of all 16 strains, unless the number of mature fruits was less than 30, in which event all mature fruits were taken. The minimum number of fruits was 13, but was less than 20 on only four plots.

From 21 to 27 fruits were taken at random as a sample from each fertilizer plot on the first date of sampling; on all except three plots, the number was 25. On the second sampling date, the number in a sample was 30 in all cases. The same measurements were made on the tomato fruits as on the cabbages.

The fertilizer plots in the study were certain duplicated plots of a truck crop fertilizer experiment which had been in progress since 1917, and in which the crops were grown in a 4-year rotation, consisting of cabbage, potatoes, tomatoes, and sweet corn in the order named, during the past 8 years. [A full description of the plan of these experi-

ments is presented in Bulletin 210 of the Pennsylvania Agricultural Experiment Station (13).]

Plots were selected in this study so as to indicate the possible effects of nitrogen, phosphorus, or potash on fruit size and form. The fertilizer mixtures were such that the amount of each element ranged from zero through a medium to a maximum amount, while the other two elements remained constant at a medium amount. The medium amounts of the three plant foods were: N, 60 pounds per acre; P_2O_5 , 100 pounds per acre; and K_2O , 80 pounds per acre. The maximum amounts were: N, 90 pounds per acre; P_2O_5 , 150 pounds per acre; and K_2O , 120 pounds per acre, or $1\frac{1}{2}$ times the medium application. All plants in both parts of the study were given good care as regards plant-growing methods, disease and insect control, and cultivation.

Beets.—Five varieties of beets were planted in a Latin square, the plots in each case consisting of a single row 27 feet long. Each variety was planted once in each of five columns and five rows of plots. The rows constituting the plots of the different varieties were 36 inches apart, and the different rows of plots formed five continuous rows through the field. Midway between these rows and outside the outer two rows of the strain planting, a single variety was planted in continuous rows. These rows were considered as constituting a second Latin square, in which the plots, all of which were planted with the same variety, duplicated as nearly as possible the soil conditions of adjacent parallel plots of the first Latin square.

Seed of all varieties, including the check just described, was weighed into lots of equal size, 7.65 grams for each plot, and these were planted at a uniform rate by hand. When the seedlings were well established, they were thinned to a uniform stand of five plants to the foot of row; no conscious choice of the strongest plants was made.

The soil was fertilized with 760 pounds of 4-16-4 commercial fertilizer to the acre, broadcast with a grain drill before planting the seed. Irrigation from an overhead sprinkler was used when general observations indicated that it might be beneficial.

Measurements were begun on September 2, and were completed within a period of about 2 weeks. All plots in each column were completed in order, proceeding from the first to the last column, and from the first to the last row within each column, including plots of both Latin squares.

Measurements included the polar and three transverse diameters, made on an axial section of the beet cut at random with respect to the diameter through which the section was made. The transverse diameters were equally distant from the poles and from each other, and thus were the equatorial and two quartile diameters.

These measurements were made by means of a stiff celluloid sheet 23 by 32 centimeters in dimensions ruled with two parallel sets of lines 1 centimeter apart, one set at right angles to the other, over which five radiating lines were spaced so as to intercept equal segments on the transverse set of centimeter lines (Fig. 1). The middle one of the radiating lines was identical with the middle longitudinal 1-centimeter line. The radiating lines intercepted 1-centimeter segments at

one end of the celluloid sheet, and 5.75-centimeter segments at the other, and thus enabled one to measure beets with polar diameters from 4 to 23 centimeters. In making a measurement, the scale was held over the cut longitudinal section of the beet, and was moved until the outer radiating lines passed through the poles, and the middle one of the radiating lines coincided with the equatorial diameter of the beet; the quartile diameters were located by the intersections of the other two radiating lines and the polar diameter or axis of the beet. All the desired measurements thus were made from one position of the measuring device on the axial section of the beet.

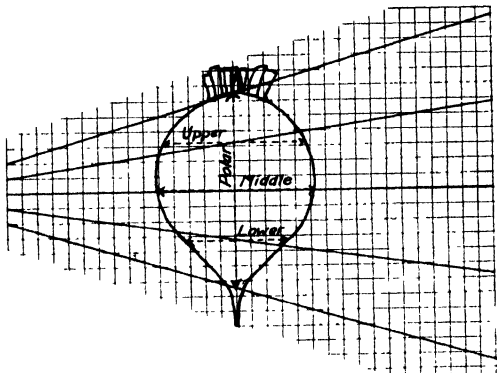


FIG. 1 Diagram of measuring device by which the longitudinal and three equidistant transverse diameters were measured simultaneously. The 1-cm squares and the radiating lines were scratched on transparent, stiff celluloid which was attached to a wooden handle, not shown in the diagram.

Measurements were made on 50 beets taken at random from each plot. Three shape indices were computed, the ratios of the upper quartile, equatorial, and lower quartile

diameters to the polar diameter. A volume index also was computed, using the formula for a prolate spheroid, $\frac{\pi}{6} \text{P.D.} \times \overline{\text{E.D.}}^2$, where P.D. is the polar and E. D. the equatorial diameter. This was recognized to be only roughly approximate, but the error was considered to be about the same for beets of similar shape.

PRESENTATION AND DISCUSSION OF DATA

Cabbage:—The data on cabbage include the weights of the heads in kilograms and the shape indices, which were computed by dividing the mean equatorial diameter of each head by the polar diameter. These data are summarized in Table I, in which are presented the number of heads measured in both spring and fall trials of each strain which was grown in both trials, the mean weight of the heads of each strain together with its coefficient of variability, and the mean shape index and its coefficient of variability. The arithmetic mean is used in each case, though it has been stated [Crist (4)] that the geometric mean should be used with ratios; very small differences were found between the arithmetic and the geometric means in several cases, and the former was used, therefore, because the calculation was less laborious.

From the table, it is apparent that weight is considerably more variable than is the shape index, as shown by a comparison of their respective coefficients of variability; the coefficient of variability of weight

TABLE I—HEAD WEIGHT AND SHAPE INDEX OF CERTAIN CABBAGE VARIETIES AND STRAINS

Variety	Strain	Number of Heads	Mean Weight (Kgms)	C. V.* of Weight	Mean Shape Index	C. V. of Shape Index
<i>Spring Trials</i>						
Golden Acre	7376 Lilly	67	0.99	31.80	0.914	10.72
Golden Acre	Madsen	67	0.85	18.20	0.948	8.54
Golden Acre Elite	Madsen	66	0.77	22.98	0.941	8.60
Copenhagen Market Second Early	Madsen	66	1.15	33.04	0.950	9.89
Copenhagen Market Improved	Madsen	67	1.18	29.20	0.967	11.47
Glory of Enkhuizen . . .	Madsen	61	1.15	35.40	1.040	12.88
<i>Fall Trials</i>						
Golden Acre	7376 Lilly	25	1.04	22.78	0.98	10.71
Golden Acre	Madsen	23	1.14	24.29	1.01	10.00
Golden Acre Elite	Madsen	25	0.97	21.13	1.01	10.69
Copenhagen Market Second Early	Madsen	24	1.32	27.95	1.07	12.61
Copenhagen Market Improved	Madsen	23	1.28	26.64	1.04	10.00
Glory of Enkhuizen . . .	Madsen	21	1.33	29.24	1.17	10.34

$$*C. V. \text{ the coefficient of variability} = \frac{\text{Mean}}{\text{Standard Deviation}} \times 100$$

is about three times as much on the average as is that of the shape index. On this account, differences required for significance are relatively smaller in shape index than in weight. For example, a difference of 0.18 kg between the mean head weights of Glory of Enkhuizen in spring and fall trials, or 14.5 per cent of the mean of the two, is not significant, the probabilities computed by the method of Fisher (7) being approximately 0.3; the difference of 0.13 in mean shape index, or 11.8 per cent of the mean of the two plantings of the same variety, is highly significant, the probabilities being less than 0.01.

In all varieties, both mean head weight and mean shape index are greater in the fall trials than in the spring trials. This fact suggests that the more distinctly oblate form may be associated with larger size in cabbage varieties. The coefficient of correlation of head weight and shape index of Madsen's Copenhagen Market Improved, in spring trials in which 67 heads were measured, was found to be $+0.349 \pm 0.0722$, a significant correlation. It has been stated by Boswell (2), however, that the transverse diameter of cabbage heads tends to be greater in relation to height in southern than in northern regions of the United States. This may indicate that greater shape index (associated with more oblate form) is associated with higher temperature during the growth period.

Tomatoes:—Table II contains data on several different varieties and strains of tomatoes, certain plots of which were studied on August 5, early in the harvesting season, and all of which were observed on duplicated plots on August 19, when most varieties were yielding rather abundantly. A comparison of results from the same respective

TABLE II—THE INFLUENCE OF SEASONAL AND OTHER CONDITIONS ON THE FRUIT WEIGHT AND SHAPE INDEX OF CERTAIN TOMATO VARIETIES AND STRAINS

Variety and Strain	Plot Number	Picking Date (August)	Number of Fruits	Mean Weight (Kgms)	C. V. of Weights	Mean Shape Index	C. V. of Shape Index
Earliana Eastern States	1	5	35	0.11	34.54	1.23	15.61
	1	19	30	0.10	47.00	1.25	13.68
	2	19	30	0.11	35.45	1.26	10.02
Penn State Earliana C. E. Myers	1	5	62	0.15	32.00	1.22	10.41
	1	19	30	0.13	37.80	1.28	9.29
	2	19	30	0.10	46.00	1.26	10.55
Penn State C. E. Myers	1	5	18	0.12	21.66	1.07	5.60
	1	19	25	0.16	36.81	1.21	12.39
	2	19	25	0.12	39.16	1.21	6.36
Scarlet Dawn A. S. Gro. M2034	1	5	21	0.17	30.58	1.15	9.39
	1	19	20	0.12	11.66	1.15	8.00
	2	19	28	0.12	42.50	1.18	11.86
Bonny Best Landreth	1	19	30	0.10	31.00	1.19	6.47
	2	19	30	0.10	39.00	1.17	9.82
John Baer A. S. Gro. U41 3	1	19	30	0.11	40.90	1.19	9.15
	2	19	13	0.12	25.83	1.18	6.95
Marglobe Glick	1	19	13	0.14	24.28	1.10	3.72
	2	19	15	0.12	55.83	1.14	9.47
Master Marglobe Stokes	1	19	26	0.11	42.72	1.12	6.69
	2	19	20	0.13	32.31	1.11	8.10
Indiana Baltimore Indiana Cannors	1	19	12	0.18	34.44	1.36	7.64
	2	19	19	0.13	44.61	1.26	11.11
Greater Baltimore Landreth Certified	1	19	29	0.13	34.61	1.44	10.90
	2	19	15	0.11	46.36	1.26	8.49

plots on August 5 and August 19 indicates the changes, if any, which occurred in fruit form and weight as the season advanced, while comparisons of results from duplicate plots show the influences of soil and other unknown conditions on these characteristics.

The mean shape index, measured and calculated in the same way as that of cabbages, is seen to be greater on August 19 than on August 5, on all plots which were measured twice, except on that of Scarlet Dawn, on which it remained unchanged. The differences are probably insignificant, however.

Variation among mean weights and mean shape indices from duplicate plots of the same variety may be observed; the differences between mean weights, however, generally are relatively greater than the respective differences in mean shape index. The maximum difference in mean shape index between two plots of a single strain at the same picking is that between the two plots of Landreth's Certified Greater Baltimore, which is 0.18, or 13.3 per cent of the average of the mean shape indices of the two plots; the corresponding difference in mean weight is 16.6

per cent of the average of the two plots. For the greater part, however, the differences in mean shape index between two plots of the same strain are inconsequential, while differences in mean weight greater than 10 per cent of the average of duplicate plots occurred in 10 different strains. The maximum difference between mean weights of duplicate plots is that for Indiana Baltimore, or 0.05 kg, which is 32.3 per cent of the average of the two plots.

The mean shape index of a given strain is generally greater, the greater the mean weight, in cases where the mean weight of fruits from one plot is noticeably greater than that from the second plot of the same strain.

Data on the influence of different fertilizers on fruit weight and form of tomatoes are presented in Table III. Measurements were made on duplicate plots, and the plots were selected among those of a general field experiment to show the effect of the largest amount of each plant food element in a complete fertilizer, in comparison with a fertilizer without the particular plant food element, but with the amounts of the other two the same as in the complete fertilizer, and the data are grouped so as to present this comparison. In addition, results are included from a complete fertilizer mixture with the medium amounts of the different plant food elements just stated, so that comparisons may be drawn among fertilizers without a given element, with a medium amount, and with a relatively large amount of this plant food element. Results are presented also from a manure treatment which has produced the highest yields of tomatoes on the average, throughout the duration of the experiments.

Data from the first date of sampling on August 6 are presented in the part of the table on the left, and those from the second sampling on August 27 are shown on the right.

The same relation of variability in weight and in form that was found in cabbage and in tomato varieties is evident also in Table III, that is, the variability of weight is relatively much greater than that of the shape index used. The mean weight of fruits from all plots in the first sampling, 0.15 kgm, is significantly greater than that in the second sampling, or 0.13 kgm. The mean shape index of the second sampling, 1.15, is greater than that of the first sampling, 1.12, but this difference is not significant.

The smallest fruits were produced on plots without phosphorus, and their shape index was significantly smaller than that of the larger fruits produced on the plots receiving the maximum amount of phosphorus, and also smaller than that of fruits from plots receiving the maximum amount of nitrogen in complete fertilizer. Other differences associated with fertilizer treatment, however were not found to be significant.

The mean coefficients of variability of shape index are 8.3 and 10.8 in the first and second samplings, and those of weight are 29.3 and 39.1 respectively. On the basis of these degrees of variation, the number of fruits required to determine significant differences may be estimated according to the formula of Livermore and Neely (11), as follows:

TABLE III—EFFECT OF FERTILIZERS ON FRUIT SIZE AND SHAPE INDEX OF TOMATOES

Treatment (Pounds per Acre)	Plot	Number of Fruits	Mean Weight (Kgrms)	C. V. Weight	Mean Shape Index	C. V. of Shape Index	Number of Fruits	Mean Weight (Kgrms)	C. V. Weight	Mean Shape Index	C. V. of Shape Index
<i>First Picking August 6</i>											
30 tons manure	1	25	0.14	39.2	1.13	8.3	30	0.12	42.5	1.13	11.1
	2	25	0.15	20.0	1.12	6.6	30	0.14	38.5	1.15	6.7
60 N 100 P ₂ O ₅ 80 K ₂ O	1	25	0.14	46.4	1.12	11.8	30	0.13	40.9	1.14	11.1
	2	25	0.14	25.0	1.12	7.9	30	0.13	43.0	1.15	11.7
100 P ₂ O ₅ 80 K ₂ O	1	25	0.16	20.0	1.12	8.3	30	0.12	57.5	1.22	10.6
	2	25	0.15	26.0	1.14	8.1	30	0.13	46.1	1.16	14.1
90 N 100 P ₂ O ₅ 80 K ₂ O	1	25	0.18	30.0	1.19	10.5	30	0.12	44.1	1.13	18.0
	2	25	0.14	30.0	1.12	7.3	30	0.13	39.2	1.16	10.6
60 N 80 K ₂ O	1	21	0.12	20.8	1.04	6.9	30	0.13	40.7	1.16	8.4
	2	21	0.12	39.1	1.06	8.2	30	0.13	29.2	1.12	11.5
60 N 150 P ₂ O ₅ 80 K ₂ O	1	25	0.17	22.9	1.15	6.2	30	0.17	38.2	1.20	12.7
	2	25	0.16	23.1	1.12	6.9	30	0.12	26.6	1.16	6.1
60 N 100 P ₂ O ₅	1	25	0.16	39.3	1.14	10.8	30	0.12	35.0	1.14	9.3
	2	25	0.15	19.3	1.13	5.7	30	0.12	27.5	1.08	9.8
60 N 100 P ₂ O ₅ 120 K ₂ O	1	27	0.13	39.2	1.13	12.5	30	0.12	39.1	1.16	11.6
	2	25	0.15	28.0	1.12	7.1	30	0.12	37.5	1.15	9.2

TABLE IV—PART I—INDICES OF FORM AND SIZE OF BEET VARIETIES, WITH ANALYSIS OF VARIANCE

	Column 1 Variety Check	Column 2 Variety Check	Column 3 Variety Check	Column 4 Variety Check	Column 5 Variety Check
Row 1					
Upper Index . .	B	A	E	C	D
Middle Index . .	0.99 0.76	0.87 0.78	1.02 0.82	0.98 0.77	1.08 0.79
Lower Index . .	1.04 0.82	0.91 0.84	1.09 0.90	0.98 0.83	1.16 0.87
Volume Index . .	0.76 0.61	0.61 0.65	0.79 0.69	0.73 0.62	0.84 0.67
	53.0 100.9	81.6 84.1	61.3 65.0	72.4 94.8	105.1 79.4
Row 2					
Upper Index . .	D	B	C	A	E
Middle Index . .	1.10 0.77	1.00 0.76	0.94 0.73	0.87 0.81	1.09 0.81
Lower Index . .	1.15 0.84	0.98 0.85	0.94 0.83	0.95 0.87	1.16 0.92
Volume Index . .	0.82 0.65	0.65 0.65	0.71 0.65	0.69 0.64	0.87 0.71
	99.3 92.9	64.6 83.2	73.6 88.6	99.5 84.7	59.4 89.2
Row 3					
Upper Index . .	A	D	B	E	C
Middle Index . .	0.82 0.74	1.05 0.79	0.97 0.73	1.02 0.81	0.93 0.84
Lower Index . .	0.85 0.78	1.06 0.85	0.97 0.85	1.09 0.87	1.01 0.89
Volume Index . .	0.55 0.60	0.70 0.65	0.69 0.67	0.75 0.67	0.72 0.69
	61.4 75.4	94.6 98.1	64.0 95.5	64.4 80.2	82.6 82.9
Row 4					
Upper Index . .	E	C	A	D	B
Middle Index . .	1.00 0.72	0.85 0.75	0.84 0.64	0.99 0.76	1.02 0.78
Lower Index . .	1.05 0.78	1.02 0.80	0.90 0.91	1.07 0.82	1.08 0.89
Volume Index . .	0.75 0.62	0.71 0.58	0.65 0.76	0.78 0.60	0.76 0.70
	49.6 68.0	82.0 97.3	82.8 91.7	80.4 70.0	42.3 85.2
Row 5					
Upper Index . .	C	E	D	B	A
Middle Index . .	0.87 0.75	1.03 0.75	0.94 0.71	0.98 0.76	0.81 0.76
Lower Index . .	0.97 0.85	1.08 0.86	0.99 0.82	1.00 0.87	0.86 0.85
Volume Index . .	0.69 0.64	0.85 0.66	0.93 0.62	0.67 0.67	0.61 0.66
	62.1 70.0	65.5 80.5	99.1 85.7	37.2 77.3	63.9 70.4

TABLE IV—PART II—INDICES OF FORM AND SIZE OF BEET VARIETIES, WITH ANALYSIS OF VARIANCE

Source of Variation	Degrees of Freedom	Mean Squares or Variances							
		Upper Index		Middle Index		Lower Index		Volume Index	
		Variety	Check	Variety	Check	Variety	Check	Variety	Check
Total.....	24	0.00729	0.00171	0.00748	0.00133	0.00779	0.00165	335.72	108.21
Columns.....	4	0.00490	0.00382	0.00319	0.00338	0.00410	0.00369	115.71	68.28
Rows.....	4	0.00132	0.00194	0.00367	0.00032	0.00291	0.00012	125.60	82.99
Varieties.....	4	0.03426	0.00088	0.03360	0.00062	0.03099	0.00117	1420.67	101.53
Error	12	0.00110	0.00112	0.00148	0.00122	0.00292	0.00164	104.10	132.15
Standard deviation $\pm$		0.0332	0.0335	0.0385	0.0349	0.0541	0.0405	10.20	11.50
Percentage difference for significance ..		4.35	5.38	4.82	5.25	9.38	7.86	17.98	17.57
Means of Varieties									
Variety		Upper Index		Middle Index		Lower Index		Volume Index	
		Variety	Check	Variety	Check	Variety	Check	Variety	Check
		A	0.842	0.746	0.894	0.850	0.622	0.662	77.84
	B	0.992	0.758	1.014	0.856	0.706	0.660	52.22	88.42
	C	0.914	0.768	0.984	0.840	0.712	0.636	74.54	84.72
	D	1.032	0.764	1.086	0.840	0.814	0.638	95.70	85.22
	E	1.032	0.782	1.094	0.866	0.802	0.670	60.04	76.58

$N = \left(\frac{\text{ratio} \times \sqrt{2} \times \text{P.E.s}}{D} \right)^2$ where N is the number of individual

required for the desired ratio between the mean difference and its probable error, D is this mean difference expressed as per cent of the mean, and P.E.s is the probable error of a single variate expressed as per cent of the mean. With a coefficient of variability of 8.3, for example, the probable error of a single variate, expressed in per cent of the mean, is $.6745 \times 8.3$, or 5.598. For a 5 per cent difference, therefore, and a ratio for significance of 3.2, N will be approximately 25. For populations having the other coefficients of variability stated above, or 10.8, 29.3 and 39.1, the numbers required for a significant difference of 5 per cent would be 43, 317, and 566, respectively. In other words, it would require 12.7 times as many fruits in the first sampling, and 13.2 times as many in the second sampling, to determine a significant difference of 5 per cent in weight, as it would to determine a similar difference in shape index.

TABLE V—PERCENTAGES OF OVATE OR TOP-SHAPED BEETS OF DIFFERENT VARIETIES ON DIFFERENT PLOTS AS ARRANGED IN THE FIELD, WITH ANALYSIS OF VARIANCE

	Column 1 Variety Check	Column 2 Variety Check	Column 3 Variety Check	Column 4 Variety Check	Column 5 Variety Check
Row 1	B 76 44	A 76 44	E 88 48	C 74 44	D 82 24
Row 2	D 76 36	B 94 42	C 74 40	A 78 60	E 70 34
Row 3	A 84 52	D 88 48	B 94 38	E 96 48	C 66 54
Row 4	E 68 42	C 80 50	A 68 54	D 86 68	B 82 30
Row 5	C 52 44	E 88 40	D 94 50	B 98 42	A 78 28

Source of Variation	Analysis of Variance		
	Degrees of Freedom	Mean Square or Variance	
		Varieties	Check
Total	24	121.35	92.14
Columns	4	221.20	219.04
Rows	4	60.10	77.44
Varieties	4	293.20	57.04
Error	12	51.17	74.77
Standard deviation, $\pm$		7.15	8.65
Required for significance, per cent		11.32	24.80

	Means of Varieties				
	A	B	C	D	E
Variety	76.8	88.8	69.2	85.2	82.0
Check	47.6	39.2	46.4	45.2	42.4

Beets.—Records on beets consisted of the polar diameter and three transverse diameters in planes equidistant from each other and from the poles, on each of 50 beets taken at random from each plot. From these diameters, three indices of shape were computed for each beet, consisting of the ratios between the separate transverse diameters and the polar diameter, and these are designated as the upper, middle, and lower index, with reference to the natural position of the beet in the soil. A volume index also was computed for each beet, as described earlier. In addition, all beets of each sample were sorted into arbitrary shape classes, such as globular or ovate, etc., and the percentages of each lot which were included in each shape class were computed.

Summaries of the foregoing data are presented in Tables IV and V. The mean indices or the percentages for the different plots are arranged in the tables in the same order as the plots occurred in the Latin square of plots in the field. In each table is included the analysis of variance according to the method of Fisher (7), Love (12), and Snedecor (21).

The variance due to varieties is seen to be much greater than that due to any other source, in the plots on which the five different varieties were planted; in the plots which were planted with one variety only, but which were treated in the computations as if they had been planted with five varieties, in the same arrangement as that in which the five different varieties were actually planted, variance due to variety is of the same order as that due to known causes, such as rows or blocks (columns) in the field. Significant differences appear between any two of the varieties except D and E in upper shape index; between any two except B and C and D and E in the middle index; between any two except D and E in the lower shape index; and between any two except A and C and B and E in volume index (Table IV). In the plots of the single or check variety, no significant differences due to variety are found when these are treated as if they had been planted with the different varieties, as is to be expected.

In Table V, in which are presented the percentages of ovate or top-shaped beets of the different varieties and of the check variety treated as if different varieties had been used, the same relation is evident as that which appeared in Table IV, in connection with variance due to varieties, that is, variance due to varieties was the greatest source of variation in the analysis of the different varieties, but was among the less important sources of variation in the check variety. Significant differences are present between C and any of the other varieties and between A and B, and the difference between any of the five varieties and the check variety is significant.

Variation in volume index is relatively greater than that in any of the shape indices, of which the lower index is relatively the most variable.

It is interesting to note that the error of the experiment is found to be almost the same, whether determined by analysis of variance of the five varieties or of a check variety treated as if there were five varieties. The differences between the respective errors found among the shape indices are relatively less than those among volume indices and among percentages of beets of a given shape.

SUMMARY

Studies reported in the foregoing paper indicate that certain numerical indices of form of vegetables which have been used by several investigators may be relied upon to reveal differences among varieties or treatments, because they are less subject to variation from unknown causes than are the commonly used quantitative measures of size and weight. The form of the marketable portion of cabbage and tomatoes is shown to be influenced by seasonal and cultural conditions such as fertilizer treatment. Shape indices were found to reveal differences among beet varieties more certainly than did the percentages of the different varieties which were grouped into arbitrary shape classes.

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Further Studies of Tomato Defoliation

By JOHN H. MACGILLIVRAY and R. W. SAMSON, *Purdue University, Lafayette, Ind.*

A PREVIOUS paper (2) has shown that age of plant and nutrition are factors which affect defoliation as well as the importance of a large amount of available plant food late in the season. This paper presents evidence to show that an acre of tomatoes requires more available nutrients than corn, wheat, or barley. The greatest absorption occurs after the middle of August. Some preliminary data are included to indicate that the composition of a tomato plant has some effect on its infection with *Septoria lycopersici*.

In Fig. 1 will be found a comparison of the relative amounts of nitrogen, phosphoric acid, and potash in the above ground portions of tomatoes, field corn (1), wheat (3) (at Bernberg, Germany), and barley (3) (at Bernberg, Germany) at different periods of the season. In the case of the tomatoes, the work represents the averages of five plants at each sampling period obtained in 1933, 1934, and 1935 at monthly intervals. This work on field corn and tomatoes was done on soil at Lafayette, Indiana. In all the four crops mentioned there was an increase in the pounds of nutrients up to the time of maturity and then in a few cases there was a decline. The tomato plant seems to use more nutrients than corn, wheat, and barley. The yield of 20 tons per acre included both the green and ripe tomatoes.

There is one distinct difference between tomatoes and the other three crops examined in that the tomato plants bloom over a 3 month period, while the others pollinize in a fairly short period of a week or two. These latter crops may drain nutrients out of the remainder of the plant to mature their fruit without greatly influencing the crop. In the tomato this drain affects the later set fruits. Barley, wheat and corn show a cessation or decrease in the amount of nutrients contained at the mature stages, while the tomato plant shows an increasing absorption until frost.

The pounds of nutrients contained, as compared to the average percentage of defoliation previously published (2), are shown in Fig. 2. As the plant grows larger and the absorption of nutrients is inadequate, the

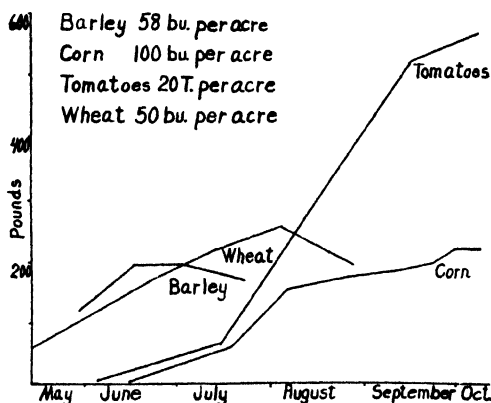


FIG. 1. The pounds of nitrogen, phosphoric acid, and potash found in the aerial portions of an acre of tomatoes, corn, wheat, and barley at different times throughout the season. The tonnage of tomatoes includes both green and ripe tomatoes. Reference (1, 3).

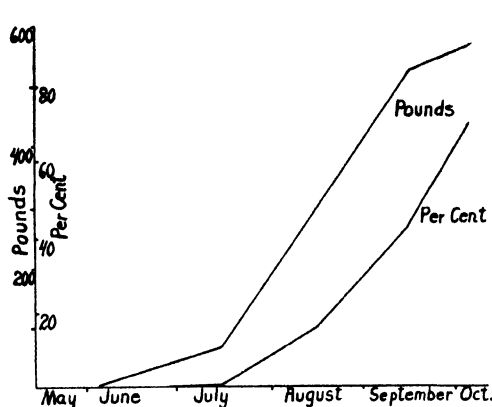


FIG. 2. The relation between percentage of defoliation at different periods and the pounds of nutrients removed by the tomato plant.

percentage of defoliation becomes greater. The arrangement of the percentage and total nutrient scales are more or less arbitrary, but the relationship chosen is believed to be conservative. The percentage scale (Fig. 2) for defoliation is 80 per cent at the same point as 500 pounds of nutrients. The percentage scale may be reduced to 40 per cent at the same point as 500 pounds of nutrients without changing the relative position of the lines, except on October 5.

These data indicate that $6\frac{1}{4}$ tons of ripe tomatoes will remove from the soil 24.7 pounds of nitrogen, 8.4 pounds of phosphoric acid, 39.9 pounds of potash, making a total of 73 pounds. Fifty bushels of corn and 33 bushels of wheat will both remove 74 pounds of nutrients. The tomatoes in 1933 produced 4.2 tons per acre of ripe fruit; in 1934, 5.7 tons; and in 1935, 19.2 tons. Both 1933 and 1934 were years of large vine growth and more green than ripe fruits. The percentage nutrients removed by the ripe fruit in comparison with the total amount in the plant was 12 per cent in 1933, 8.5 per cent in 1934, and 44.8 per cent in 1935. In the case of the other crops, corn removes 57.0 per cent of the total nutrients in the ear, wheat 57.9 per cent in the grain, and barley 49.4 per cent in the grain. The maximum number of pounds of nutrients found in the tomato vine and fruit are as follows: 1933, 518 pounds; 1934, 713 pounds; and 1934, 584 pounds.

EFFECT OF SEPTORIA ON DEFOLIATION

Previously it has been shown (2) that inadequate amounts of nitrogen, phosphoric acid, and potash will cause loss of leaves from tomato plants. These experiments were carried a step further and the effects were studied of ample nutrients and inadequate nutrients, combined with and without infection with *Septoria* leaf spot. Indiana Baltimore tomato seed was planted and the seedlings transplanted to greenhouse soil in four inch pots. When the first blossom cluster opened the soil was washed free from the roots and the plants were transplanted to sand or soil.

In 1933, plants were transplanted to soil of low fertility in greenhouse benches. A portion of these plants were inoculated three times by spraying them with a suspension of *Septoria* spores from agar cultures and covered with wet muslin for 36 hours. The inoculated plants were 29.6 per cent defoliated and the noninoculated plants were 16.3 per cent defoliated.

In 1935, plants were transplanted to sand or soil in 2 gallon glazed pots on August 19, and the experiment terminated on October 18. Twenty plants were grown in sand and a similar number in rich compost soil. As the plants in sand received little plant nutrients they represented starved plants. Half of both the sand and soil plants were inoculated with a suspension of *Septoria* spores and inclosed with a muslin covering as previously described. The inoculations in 1935 were at the rate of about two hundred million spores per plant.

The combining of the effects of inadequate plant nutrients and *Septoria* infection shows some interesting data which are found in Table I. The percentage of defoliation is greatest on the plants grown in sand without added nutrients. The *Septoria*-inoculated plants have a greater percentage of defoliation than the noninoculated plants. By September 14, the plants grown in sand were distinctly in a poorer nutritional state and about this time there was a very great loss of leaves. It was very noticeable that a large proportion of the leaves fell from the stems within a week or 10-day period. After this a small tuft of three to five leaves remained at the top of the stem and leaf fall almost ceased.

The *Septoria* lesions were counted on various leaves and the results are found in Table I. The September 10 results are reported on per leaf basis and the other results on a square inch basis, although all lesions on the whole leaf were counted. The soil culture plants were five times larger than the sand culture plants. It is evident that the bottom leaves have a greater infection and also these leaves received more applications of *Septoria* spores due to their age. The under-

TABLE I—THE EFFECT OF NUTRIENT STARVATION AND INOCULATION WITH *SEPTORIA* SPORES UPON DEFOLIATION 1935

Date	September 10 <i>Septoria</i> Spots per Leaf		September 27 <i>Septoria</i> Spots per Square Inch		October 11 <i>Septoria</i> Spots per Square Inch		Defoliation of <i>Septoria</i> Inoculated Plants (Per Cent)	Defoliation of Plants not Inoculated with <i>Septoria</i> (Per Cent)
	8th from Bot- tom	Near top	Bot- tom	Top Inocu- lated Leaf	Bot- tom	Top Inocu- lated Leaf		
Sand cultures								
No nutrients	34.4	4.3	44.7	4.3	46.2	5.0	67.8	43.1
Greenhouse								
Soil	14.6	0.0	13.6	0.1	23.6	3.1	19.1	5.4

Spores sprayed on plants, and plants were inclosed in wet cloths for 36 hours August 26, September 5, 14, and 28.

nourished plants had the most infection. There seems a tendency in the case of the soil culture plants for the top leaves to have more infection late in the season. As all plants were grown in 2-gallon jars it is likely the plants grown in soil may have been more poorly nourished late in the season and this was the reason for the increased infection on the top leaves. This should be further tested before coming to a final conclusion. The well nourished plants grown in greenhouse soil do not seem to suffer as great defoliation, nor as much leaf infection, as the starved plants.

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Flower Structure and Its Relation to Fruit Setting in the Tomato

By FREEMAN S. HOWLETT, *Ohio Agricultural Experiment Station,
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ABSTRACT

The complete paper will be published elsewhere.

THE particular aspect of tomato flower structure with which this paper is concerned is the relative length of the stamens and the pistil. Evidence is presented concerning the extent to which the relative length of the pistil and stamens is modified by environment. Consideration is also given to the effect of this modification upon the ability of the respective varieties to set fruit under several different environmental factors.

It was apparent that as a result of conditions inducing a mild deficiency of carbohydrates reserves, there was an increase in the length of the pistil in practically all of the 40 varieties examined. The change was decidedly less in some varieties than in others. Those varieties exhibiting a comparatively slight change in the length of the pistil set more freely under conditions of mild carbohydrate deficiency than those showing the greatest change in length of the pistil. The change in the length of the pistil concerns not only the adaptation of different varieties to greenhouse culture, but also involves one of the frequent causes of the failure of tomato flowers to develop into fruits.

Carbon Dioxide Assimilation of the Tomato¹

By E. P. CHRISTOPHER, *Rhode Island State College, Kingston, R. I.*

RECENT work (4, 6, 2) with the Heinicke and Hoffman apparatus (5), on the influence of various treatments upon the carbon dioxide assimilation of apple leaves, suggested that some problems of the tomato grower might be attacked, using similar methods. A study of the normal variations in the photosynthetic activity of the tomato leaf was considered to be a necessary preliminary to studies of the influence of spray materials or nutrients.

Tomato plants of the Waltham Field Station Greenhouse Strain were set in a greenhouse bench in the fall of 1935, and grown to a height of about 4 feet. On January 17, three leaves similarly exposed were selected about 1 foot from the top. The areas were carefully measured, and a copper tube was placed beneath the mid rib of each, and extended to the tip of the leaf. A cellophane bag was used to enclose the leaf during the period of the run. The leaves had areas of 76.6, 96.7, and 98.5 cm², respectively, and received approximately 100 liters of air per hour.

Nine hourly runs were made during the day of January 18, starting at 6:45 a.m. About 5 minutes were lost between each run because of the necessity of changing bottles. The final hourly run was terminated at 4:25 p.m., when the maximum light reading on a Weston Illuminometer was 160 F.C. Seven 2-hour runs were made during the night, and nine hourly runs the next day, starting at 7:05 a.m. The results, expressed as milligrams of carbon dioxide assimilated or given off, per 100 cm² of leaf surface (one side) per hour, are shown in Fig. 1.

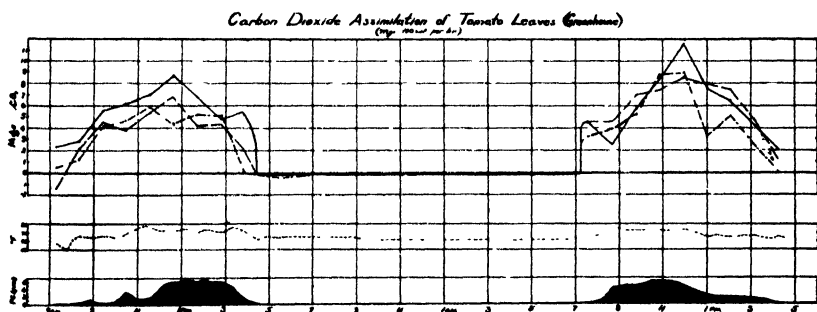


FIG. 1. Carbon Dioxide assimilation of tomato leaves for 2 days and 1 night (mgs. 100 cm² per hour).

The assimilation rate for any given hour, when this method of gas analysis is used, must, of course, be an average for the hour, and any fluctuations during that time will not be shown. Light and temperature readings were taken three times during each run; therefore, the lines showing these variables show less fluctuation.

¹Presented by permission of the Director of Research as Contribution No. 500 of the R. I. Agricultural Experiment Station.

All three leaves reached their highest assimilation rate between 11 a.m. and 1 p.m., both days. Leaf 3 attained a rate of 8.66 mgs per 100 cm² per hour on the first day, and 11.24 mgs the second day. In general, the assimilation rate of all leaves followed a similar course. It is apparent that with the tomato under these conditions, a higher rate of assimilation in the early morning than in the afternoon, is not obtained (3). An examination of the light available is of interest. It will be noted that the intensity of light was very low during the first part of the day, January 18, while on January 19 a high light reading was secured early in the morning, but it was rather low after 1 p.m. The assimilation rate of all leaves increased rapidly on the morning of January 18 in spite of low light, and held up about as well on the afternoon of January 19 when the light intensity was greatly reduced.

These data show a variation in the assimilation rate from hour to hour, or from day to day. There is a tendency to follow a rather definite course, however, in spite of changes in known environmental factors. Data presented later indicate, however, that the total assimilation for a period of several hours may vary greatly from day to day.

The use of whole plants instead of individual leaves would make the measurement of transpiration losses and carbon dioxide assimilation at the same time, quite simple. Therefore, tomato plants were transplanted to 4 inch pots, the inner surfaces of which had been treated with paraffin. When they had become well established, a wax paper top was put in place, and cotton was used to seal the opening about the stem. By weighing the potted plant at the beginning and end of the run, a reasonably accurate measure of water loss could be obtained. A copper tube was lashed to the side of the pot and carried up to a point just above the top of the plant. The plants had a leaf area of between 200 and 250 cm² and an air flow rate of from 175 to 200 liters per hour. A cellophane chamber to enclose the whole plant was made, and a carbon dioxide assimilation run begun. In Table I the assimilation and transpiration rates of four plants, for a 5 hour period on six consecutive days, are presented. These data are very consistent and seem to indicate that this method may be substituted for the individual leaf method. It is interesting to note that here is a closer relationship between the transpiration rate and the weather than between the carbon dioxide assimilation and the weather. The transpiration rate is cut much more proportionally by the rain and low light intensity on March 3. The haziness of March 5 seems to have cut down transpiration more than it did carbon dioxide assimilation.

Table II presents data showing the influence of 4-4-50² bordeaux mixture upon the carbon dioxide assimilation of tomato leaves. Eight leaves were selected, so that there were four pairs similarly exposed. The leaves were then run, December 4, 1935, to determine the relative activity of each leaf, and the even numbered leaves were sprayed at the end of the run, December 4, 11, and 13, using a small hand sprayer. Considerable variation in the carbon dioxide assimilation of the various

²In making up all of the Bordeaux mixture, chemically hydrated lime was used in place of calcium oxide, in the proportion of 1.32 parts of the hydrate to each part of the oxide called for in the formula.

TABLE I—CARBON DIOXIDE ASSIMILATION OF POTTED TOMATO PLANTS (MGs CO₂ 100 CM² PER HOUR)

1936	Time	Plant 1		Plant 2		Plant 3		Plant 4		Temperature (Degrees F)	Light Intensity F. C.	Weather
		CO ₂	Grams Water Loss per 100 Cm ² per Hour	CO ₂	Grams Water Loss per 100 Cm ² per Hour	CO ₂	Grams Water Loss per 100 Cm ² per Hour	CO ₂	Grams Water Loss per 100 Cm ² per Hour			
Mar. 2	9:15									78	2600	Clear
	2:15	4.69	0.63	3.34	0.65	4.29	0.97	3.57	0.59	70 76	2600 3000	
Mar. 3	9:00									60	420	Rain
	2:00	3.53	0.28	2.98	0.23	4.03	0.24	2.23	0.32	74 70	840 1600	
Mar. 4	8:30									72	2600	Clear
	1:30	3.81	0.53	2.46	0.39	4.16	0.66	2.54	0.50	74 72	2800 2600	
Mar. 5	9:10									72	1400	Hazy
	2:10	3.66	0.28	3.22	0.39	4.77	0.37	3.81	0.34	66 70	720 1800	
Mar. 6	9:00									58	2800	Clear
	2:00	6.33	0.55	8.56	0.50	6.25	0.54	5.38	0.55	64 63	2800 2600	
Mar. 7	8:45									62	2800	Clear
	1:45	4.51	0.58	4.09	0.54	4.54	0.59	1.89	0.38	66	2000 2400	

December 13	12:45 4:45	-8.90	-12.06	7.86	2.32	-1.39	1.06	2.19	2.74	76 74 66	1200 140 0	Clear
December 14	11:20 3:20	4.25*	3.81	5.46*	6.42	6.59*	9.01	8.75*	10.65	66 76 70	600 2600 1600	Overcast
December 16	11:16 3:16	-1.71	2.03	2.77	2.90	2.96	-0.35	3.64	3.58	65 65 62	540 200 200	Overcast
December 18	11:10 3:10	5.90	4.94	7.31	8.50	9.78	10.06	9.00	9.10	73 71 67	2600 2800 2400	Clear
December 19	11:10 3:10	3.38	11.82	5.98	8.82	7.36	13.37	9.75	8.17	75 80 64	760 2200 1000	Hazy
December 20	11:32 3:32	5.79	3.52	2.51	7.07	-4.22	4.18	4.20	3.31	68 66 65	600 240 28	Overcast

*Sprayed before beginning of run.

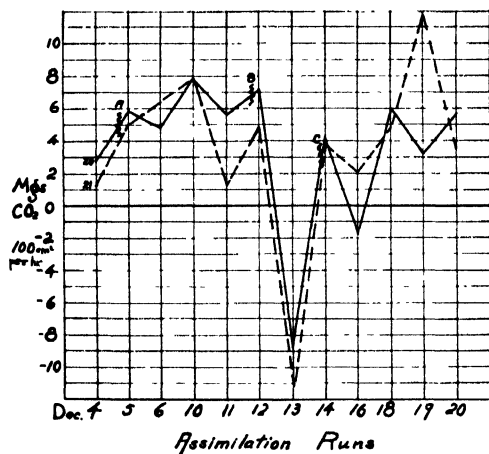


FIG. 2. Carbon dioxide assimilation of tomato leaves 20 and 21. Leaf 20 was sprayed with 4-4-50 Bordeaux at "A", "B", and "C".

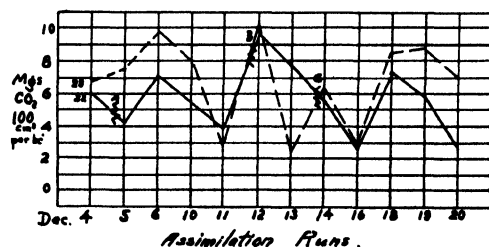


FIG. 3. Carbon dioxide assimilation of tomato leaves 22 and 23. Leaf 22 was sprayed with 4-4-50 Bordeaux at "A", "B", and "C".

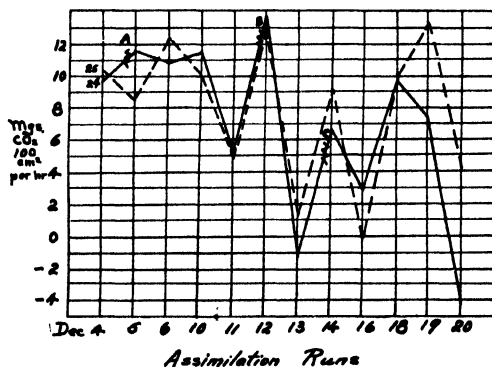


FIG. 4. Carbon dioxide assimilation of tomato leaves 24 and 25. Leaf 24 was sprayed with 4-4-50 Bordeaux at "A", "B", and "C".

leaves occurred, but it is very questionable if the spray applications had any consistent helpful or injurious effect. In order to present these variations more clearly, the assimilation of each pair has been plotted Figs. 2, 3, 4, 5). The assimilation rates of leaves 20 (sprayed) and 21 follow each other quite closely, except on the 19th when the sprayed leaf went counter to the trend, but upward instead of downward, as might be expected from the results of Childers (1). Leaves 22 and 23 follow rather closely the same assimilation rate, as do leaves 24 and 25. Leaves 26 and 27 followed each other so closely that there certainly can be no suggestion that under these conditions the spray influenced the carbon dioxide assimilation.

In Table III are presented data on the carbon dioxide assimilation of eight potted tomato plants, before and after treatment of six of them with various spray combinations. All plants were run for 5 hours, on January 27 and 28, 1936, to determine the usual relationship between the plants. Plant 1 and 2 were sprayed with bordeaux 4-4-50, plants 3 and 4 were sprayed with copper sulphate alone, of the concentration (4-0-50), plants 5 and 6 were

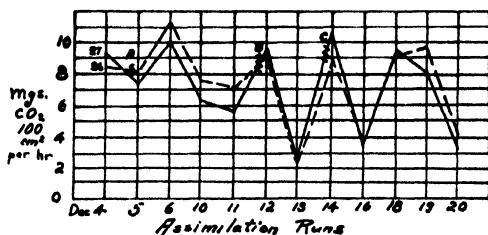


FIG. 5. Carbon dioxide assimilation of tomato leaves 26 and 27. Leaf 26 was sprayed with 4-4-50 Bordeaux at "A", "B", and "C".

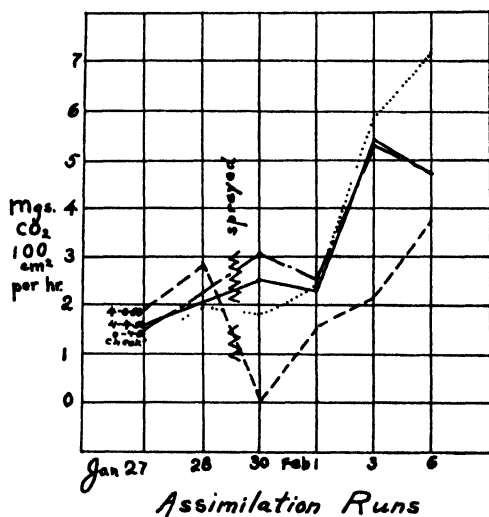


FIG. 6. Average carbon dioxide assimilation of pairs of potted tomato plants influenced by Bordeaux 4-4-50, 4-0-50, and 0-4-50, compared with an untreated pair.

sprayed with lime alone (0-4-50), and plants 7 and 8 were untreated, so that they might serve as checks. It is immediately apparent that the copper alone caused an immediate reduction in the carbon dioxide assimilation of the plants. An examination of the plants revealed small brown spots on the leaves, typical of copper injury, which we have found many times. There seems to be a marked recovery from the initial low on the 30th, however. Neither of the other two treatments, 4-4-50 bordeaux or lime alone, caused any consistent reduction in assimilation under the conditions of the experiment. The average of the two plants in each treatment is plotted in Fig. 6. The unusually high assimilation for the checks on the last day is due, of course, to the unusually high rate for plant 7. From the first figure, we had seen that these unexpected peaks may occur without apparent reason.

These data on the influence of 4-4-50 bordeaux spray are similar to those secured by Hoffman, Clore, and the writer, while working on apple leaves. The results of Clore (2), working with apple leaves, showed no reduction from bordeaux or copper, but a marked reduction from lime alone. Our results with copper, and lime alone, are directly reversed. The reduced yield and size of the tomato plant reported by Childers (1), where bordeaux 4-4-50 was used, raises an important question. Can growth and yield be markedly reduced by the bordeaux and the CO_2 assimilation rate of the leaves remain unchanged? It has been reported by Wilson and Runnels (7), that the transpiration rate of the tomato is increased by bordeaux sprays. Our tests were carried on in cellophane bags or chambers, which would be expected to main-

tain a high relative humidity about the plants during the warmest and brightest part of the day. It may be that in the field, the CO_2 assimilation is cut down by an excessive rate of transpiration induced by the spray.

CONCLUSIONS

The apparatus of Heinicke and Hoffman for measuring the carbon dioxide assimilation of apples leaves, is adapted to use on the tomato plant. The carbon dioxide assimilation of tomato leaves tends to follow a definite pattern. The assimilation rate of tomato leaves did not follow light intensity closely. Bordeaux 4-4-50 does not appear to influence carbon dioxide assimilation under the conditions of these experiments. Copper sulphate solution caused some visible spotting of leaves, and a marked reduction in carbon dioxide assimilation. Some recovery appears to take place. A lime solution failed to reduce carbon dioxide assimilation.

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Type and Severity of Fruit Cracking in Tomato Varieties

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ABSTRACT

This paper will be published in full elsewhere.

THE paper is a report on cracking data secured from 70 strains and varieties of tomatoes grown in the field at College Park in 1936.

It was apparent that the greatest and most consistent differences in cracking occurred between picking dates, as a result of variation in rainfall. However, differences between varieties were in some cases appreciable, and consistent throughout the season.

Variability in cracking data on tomatoes was extremely high. Wide differences in degree of cracking of fruits from adjacent vines of the same variety, of fruits of the same physiological age on a given vine, and even of fruits on a given cluster, were found.

Radial Cracking:—Deep radial cracking was typical of Marglobe. Other varieties showing frequent radial cracking were: Bonny Best, John Baer, Nystate, Clarks Jewel, Chalks Red Jewel, Early Detroit, Scarlet Dawn, Tri-State, and Dwarf Champion. Those varieties showing consistently less frequent radial cracking were: Pear-Shaped Red, Delaware Beauty, Brown's Special, Break O'Day, Grothens Globe, and Pritchard.

Concentric Cracking:—Most of the early varieties, such as Early June Pink, Landreth's Sunrise, Penn State, and Earliana were far more severely cracked concentrically than most late varieties. Break O'Day, Grothens Globe, and Coopers Special may be added to this group. Concentric cracking of these varieties was *relatively* more severe early in the season. As the season progressed, there was a tendency for concentric cracking of late varieties to become relatively more severe.

Relative freedom from both radial and concentric cracking was noted in Pear-Shaped Red (a small fruited variety of little commercial importance in the U. S.), and Brown's Special (a late, large-vined variety now grown to some extent for canning purposes in Maryland, but noticeably susceptible to blossom end rot in these studies). Previous observations on this variety, in which such detailed data were not taken, did not indicate such freedom from cracking.

There is an obvious need for further study of numerous varieties over a period of years, and in widely different locations. Data here presented on varied types of tomato varieties shows the general susceptibility to fruit cracking, and that apparently no variety can now be considered free of cracking. The early appearance of concentric cracking and "netting" or "russeting" of fruits of Break O'Day, Grothens Globe, and most early varieties may be closely associated with their light, open foliage.

A Comparison of Manure and Peat for Greenhouse Tomato Culture

By J. R. HEPLER, *University of New Hampshire, Durham, N. H.*

IN search for manure substitutes for the greenhouse, peat has occupied an important position in New England partly because of the ease of importing the foreign product, partly because of the large, relatively undeveloped deposits of peat in northern New England, and partly because of its wide use in poultry houses and cow stables as litter.

A house 36 x 50 with ground beds was used for the experiment. The soil consisted of about 8 inches of a composted soil made of equal parts of cow manure and heavy sods. The beds were filled with this soil in the fall of 1931 a year before the experiment was started.

The treatment consisted of the application of a 200 pound bale of German peat to each of two alternate quarters of the house, and about 750 pounds of manure to each of the other two quarters before the plants were set out in February. The yields of fall crops were so low (about 40 per cent of the spring crop), that they were not included in the yield totals. There was a slight nematode infection, but it was held in check by sterilizing the soil with steam twice a year.

The plants were set 18 inches apart in the row and the rows 3 feet apart. Each quarter of the house contained 70 plants and was a duplicate of every other quarter as far as varieties, and cultural practices were concerned.

The yield records were in ounces and are the actual yields obtained, no adjustment being made for pruning accidents or disease which killed an occasional plant or reduced its yield.

TABLE I—THE EFFECT OF MANURE OR PEAT ON THE YIELDS OF TOMATOES

Year	Yield in Ounces of 140 Plants		Per Cent Comparison	
	Manure	Peat	Manure	Peat
1932	13,607	13,659	100	100.4
1933	15,724	15,775	100	100.3
1934	25,332	23,087	100	91.1
1935	17,323	16,979	100	98.0
1936	15,422	13,578	100	88.0
Total	87,408	83,078	100	95.0

The yields of the peat plots compared very favorably with the manure plots except in 1934 and 1936. Yields in 1934 were unusually heavy and in 1936 were somewhat reduced on the peat plots by wilt (*Fusarium oxysporum*). This organism causes western blight of tomatoes and is not the common outdoor wilt (*Fusarium lycopersici*). The origin of this disease is unknown. *Fusarium* wilt does not damage the outdoor crop.

While the fertilizing elements appear rather low, especially the nitrogen and phosphorus, the plants have always made an excellent growth and show no signs of starvation. The humus content of the

TABLE II—SOIL SAMPLES ANALYZED BY AN ADAPTATION OF THE MORGAN
(1) QUICK METHOD OF SOIL ANALYSIS

Elements	1933		1936	
	Manure Plot	Peat Plot	Manure Plot	Peat Plot
pH	6.10	5.40	6.30	5.56
Nitrate nitrogen . . .	_____	_____	Low	Trace
Ammonium nitrogen	_____	_____	Very low	Very low
Phosphorus	Very high	Very high	Low to medium	Low
Aluminum	_____	_____	Medium to high	High
Magnesium	_____	_____	High	High
Manganese	_____	_____	Very low	High
Potassium	High	Very high	Very high	Very low
Calcium	_____	_____	Very high	Very high

peat areas is distinctly better than in the manured plots. During the first 6 weeks, the plants on the manure plots look a little larger but later on the others catch up and there is no difference in the time of ripening or the size of the fruit. Judging from the above results peat could be substituted for manure in tomato culture at least every other year, without impairing the yield of the crop.

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Factors Affecting the Keeping Qualities of Tomatoes in Storage

By VINCENT E. IVERSON, *Montana State College, Bozeman, Mont.*

EXPERIMENTS were initiated at the Montana State Experiment Station in 1936 to determine the effects of surface sterilization, waxing, and wrapping on the keeping qualities of tomatoes in storage.

Five lots of 40 tomatoes each of the Bonny Best variety were selected in a uniform white ripe stage and were given the following treatments:

(a) Check; (b) sterilized by washing for 5 minutes in a 4 per cent dilution of a saturated solution of chlorinated lime (unwrapped); (c) unsterilized and wrapped with medium weight vegetable parchment paper; (d) sterilized and wrapped; and (e) sterilized, waxed by dipping tomatoes in ozokerite wax at a temperature slightly above the melting point of the wax approximately 90 degrees C (wrapped).

Observations on keeping qualities after storage for 2 months at about 5 degrees C indicate a significant relationship between methods of handling and keeping qualities of tomatoes. Table I shows the observed differences.

TABLE I—CONDITION OF TOMATOES AFTER STORAGE FOR 60 DAYS AT 5 DEGREES C

Treatment	Per Cent Ripe			Per Cent White Ripe		
	Firm	Medium Firm	Soft (Decayed)	Firm	Medium Firm	Soft (Decayed)
Unsterilized unwrapped	40	40	20	0	0	0
Sterilized unwrapped . .	10	50	20	20	0	0
Unsterilized wrapped . .	60	10	20	10	0	0
Sterilized wrapped	40	60	0	0	0	0
Sterilized waxed and wrapped . . .	75	0	15*	10	0	0

*Wax coating had cracked from handling which allowed decay organisms to enter.

It appears from the table that this method of surface sterilization increases the moisture loss of tomatoes in storage without greatly affecting the development of storage rots. Ozokerite wax, which can easily be removed at the time of taking the tomatoes out of storage, has materially reduced storage rots. All tomatoes in which the waxy coating remained intact were in fine condition after 60 days in storage.

This experiment will be continued in 1937 with an effort to study quantitatively the observed differences mentioned in this paper.

Some Studies on Puffiness of Tomatoes¹

By J. B. CORNS, *Cornell University, Ithaca, N. Y.*

THE puffing of tomatoes is a rather serious problem in the South and West and has been reported from Texas, California and Florida. This condition has also been observed by the writer in Michigan and New York. It seems for the most part to be confined to the Southern states from which green wrap tomatoes are shipped. The loss to the growers may vary from 10 to 25 per cent, depending on the severity of this abnormality. An actual percentage is somewhat difficult to estimate since culling out of the puffed fruits is done both in the field and at the racking shed.

Puffed fruit for the most part is characterized by a large hollow space between the gelatinous matrix of the placenta and the outer carpellary wall. This space may vary from about 1 millimeter up to as much as 12 or 15 millimeters. Small hollow spaces may not be detrimental but large spaces make fruit lighter in weight and unacceptable for Grade U. S. No. 1 or U. S. No. 2. Such a condition may often be associated with angular fruit with few but large carpels. Often the outer carpellary walls may sag inward which may further detract from the appearance, but at the same time actually reduce the hollow area. Traub, *et al* (1) classified puffed fruits or "tomato pockets" in four different types as observed in tomatoes grown in Texas. All of these types have not been observed in fruit grown in New York. Yarnell (2) in his study of puffing from the genetic aspect, found marked variation in amount of puffing between strains of the same variety and between varieties. The variety Marglobe was found to be the variety on which puffing was most severe. He found in his crosses that factors favoring a small amount of puffing seem to be dominant.

This puffed condition appears to be brought about by an unequal rate of growth of the placenta compared to the inner and outer carpellary wall. Such a condition might be caused by a retarded growth of the placenta as influenced by the number of seeds per carpel. The number of seeds per carpel may influence the size of the placenta and this, in turn, alter the size of the carpel and the space between the placenta and the outer carpellary wall. There appears to be a direct correlation between the number of seeds per carpel and the size of the placenta. Seedless fruits or carpels are smaller than those with normal number of seeds.

In order to determine the effect of pollination methods upon puffing and numbers of seedless carpels, an experiment was carried on during the fall and winter of 1935-36. Marglobe plants of a pure-line selection were used and the plants grown to maturity in wooden boxes with inside dimensions 14 inches x 14 inches x 15 inches. Treatments were alike except for methods of pollination which were as follows:

Lot 1. Complete pollination; pollen placed on the thumb nail, then the stigma placed in the pollen.

Lot 2. Plants and blossom clusters undisturbed.

¹Paper No. 160. Department of Vegetable Crops, Cornell University, Ithaca, New York.

Lot 3. Blossoms and blossom clusters jarred every 2 days. The fruits were harvested in the turning to full pink stage, except in the final picking which consisted of the balance of the fruit which weighed 25 grams or over. The fruits were picked twice a week during the season.

TABLE I—INFLUENCE OF METHODS OF POLLINATION ON INTERIOR DEVELOPMENT OF THE FRUIT

Lot Number	Method of Pollination	Number of Plants	Number of Fruits	Per Cent of Fruit with Puffed Seedless Carpels	Per cent of Fruit with Seedless Carpels	Per Cent Seedless Carpels
1	Complete (hand)	10	130	1.5	76.2	32.3
2	No artificial pollination	10	80	7.5	91.3	60.4
3	Jarring blossoms	10	101	7.9	70.3	30.0

Lot No. 1 or the complete pollination lot had the lowest percentage of puffed fruits which were caused by lack of seeds in the carpels. The percentage of fruits with puffed seedless carpels was practically the same in the other two lots. The plants not pollinated had 60.4 per cent seedless carpels compared to 32.3 per cent for those hand pollinated and 30.0 per cent for those which were shaken. The data on seedless carpels is presented to show how it may influence the amount of puffing. Only a very small percentage of the fruits with seedless carpels puff. Seventy-six per cent of the hand pollinated fruits had seedless carpels, whereas only 1.5 per cent actually puffed and those not artificially pollinated had 91.3 per cent seedless carpels and only 7.5 per cent puffed. It does not seem that there is always a direct correlation between the percentage of fruits with seedless carpels and the amount of puffing.

This particular type of puffing which is found in seedless carpels and which may be influenced by lack of pollination, fertilization, or by environmental conditions is of minor importance compared to the more common type as found in tomatoes grown in the South. The latter type has been previously described in this paper. Puffing of the fruits due to seedless carpels may be a problem to the greenhouse tomato grower, but it does not appear to be of great importance to Southern growers.

INFLUENCE OF STAGE OF MATURITY ON PUFFED FRUITS

It was thought that the amount of puffing might be influenced by the stage of maturity. Some observations were made during the spring of 1936 in the course of an experiment with a puffing strain of the variety Texas Special. It was noted that the amount of puffing decreased if the fruits were left on the vines to ripen. A subsequent field experiment also bore out this relationship.

In the fall of 1936 some data were collected on the relation of maturity to percentage of puffing. The variety Marglobe was used and the experiment was laid out for fertilizer treatments. The block consisted

of five plots. Near the close of the season fruits of the three stages of maturity were harvested. These three stages of maturity were:

1. Mature green or those which were fully mature, but had not started to turn pink.
2. Pinks or those which were pink, but not red.
3. Ripe or those which were all or practically all red, but were still fairly firm and suitable for marketing as ripe fruit.

The ripe and pink fruits were cut and examined immediately after picking. The mature green fruits of each of the five lots were thoroughly mixed and divided into two equal lots. One lot was examined immediately and the second lot was ripened artificially. This second lot was ripened in a basement room with approximately 70 per cent relative humidity and temperature of 60 to 70 degrees F. The ripe fruits were removed and cut every 2 days as they ripened.

TABLE II—INFLUENCE OF MATURITY ON PERCENTAGE OF PUFFING

Lot Number	Number of Fruits	Mature Green Per Cent Puffed	Pink Per Cent Puffed	Ripe Per Cent Puffed	Ripened Artificially Picked Mature Green Per Cent Puffed
1	164	12.1	5.9	1.6	9.1
2	226	10.8	6.0	4.6	12.5
3	170	20.0	13.9	2.1	13.6
4	173	12.9	6.0	4.5	12.5
5	151	15.4	9.4	3.0	10.0
Averages	177	14.2	8.2	3.2	11.5

RESULTS

As shown in Table II, the percentage of puffing was influenced by the stage of maturity. It will be noted that in all lots there is a decreasing amount of puffing from the mature green to the ripe stage. The mean per cent of puffing for the mature green fruits is 14.2 per cent, for the pink fruit 8.2 per cent and for the ripe fruit 3.2 per cent. There is a small decrease in the per cent of puffs in the artificially ripened as compared with the mature green fruit. The odds of significance by Student's Method of Analysis are less than 19 to 1 between these two lots. It does not seem probable that there would be any significant decrease in puffing; however, it is probable that the sagging of the outer carpelary walls would tend to slightly decrease puffing and that a break down of the placenta and gelatinous matrix might mask the puffing.

From these preliminary data, it seems that puffed fruit of the Marglobe variety will largely recover from puffing if left on the vines until maturity. This must, in part, account for the large amount of puffing which is found in the mature green or green wrap fruits which are shipped from the South. If the fruit was left on the vine until maturity, as is the case with the canning tomatoes or those marketed as pinks or ripe, the amount of puffing would be materially reduced.

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Tomato Variety and Strain Differences in Ascorbic Acid (Vitamin C) Content¹

By W. A. MACLINN, C. R. FELLERS and R. E. BUCK,² *Massachusetts State College, Amherst, Mass.*

INTRODUCTION

THIS paper contains data bearing on the effect of variety and strain of tomatoes (*Lycopersicum esculentum*) on the vitamin C content. Effects of size of fruit, maturity and storage are also considered.

While there are a number of published reports relative to vitamin C in tomatoes, none are really comprehensive in scope and few have considered varietal strain, maturity and similar factors. That the tomato is a very good antiscorbutic is generally acknowledged, although the various reports show considerable variations in vitamin C content.

Sansome and Zilva (5) found that tomatoes with tetraploid number of chromosomes (24 pairs) have approximately 40 per cent more vitamin C than tomatoes with the diploid number of chromosomes (12 pairs). Lindstrom of Iowa (3) in a personal communication states that all cultivated varieties of tomatoes are of the diploid type, having 12 pairs of chromosomes. He further states that it is not difficult to obtain a tetraploid of any variety but they are not practical as the fruit or seed set is poor. Fellers, Clague and Isham (2) found very little difference in the vitamin C content of Stone and Marglobe varieties. In the case of apples, Smith and Fellers (6) reported marked varietal differences in vitamin C content.

The effect of variety of tomato seemed very worthy of further investigation, not only because of lack of study but also because of the increasing importance of the tomato as an antiscorbutic.

SAMPLES AND EXPERIMENTAL METHODS

The chemical determinations for ascorbic acid (vitamin C) were made by the Tillmans method (7) as modified by Bessey and King (1). The method is essentially the oxidation of ascorbic acid quantitatively with 2,6-dichlorophenolindophenol as the dye indicator.

Ninety-eight strains and varieties of tomatoes were grown on the Massachusetts Agricultural Experiment Station experimental plots. All had exactly the same fertilizer treatments and care. Six samples of each variety or strain were used, each sample consisting of a composite portion, 25 to 50 grams, of a firm, ripe tomato from a different plant of each separate variety. The composite portions were triturated in a mortar with acid-washed sand and acid mixture (3 per cent trichloroacetic acid and 2 per cent metaphosphoric acid), centrifuged for 15 minutes at 1,800 r.p.m., the serum decanted and made up to 100 cc with acid mixture, 25 cc aliquot portions were titrated with the stand-

¹Contribution No. 267. Massachusetts Agricultural Experiment Station.

²Acknowledgment is gratefully made to Professor G. B. Snyder of the Olericulture Department, who supervised the collection of seeds and the culture and harvesting of the tomatoes.

TABLE I—VITAMIN C CONTENT OF 98 VARIETIES AND STRAINS OF TOMATOES

Plot Number	Variety	Maximum Value (Mg/Gram)	Minimum Value (Mg/Gram)	Mean Value and S. D.* (Mg/Gram)	International Units and S. D.* (Ounce)
6E	Greenhouse, No. 9-1936 ..	.50	.41	.44 ± .03	249 ± 17
13A	Golden Nugget, Sutton	.50	.31	.43 ± .02	243 ± 11
8A	Princess of Wales, Sutton...	.59	.30	.41 ± .09	232 ± 51
6	Mass. Field Station, No. 7-1	.58	.29	.41 ± .09	232 ± 57
11	Ideal Forcing, Grand Rapids	.47	.30	.39 ± .06	221 ± 34
5	Mass. Field Station, No. 2-1	.50	.30	.39 ± .08	221 ± 45
6B	Mass. Field Station, No. 11-1	.54	.31	.39 ± .07	221 ± 40
6A	Mass. Field Station, No. 8-1	.49	.29	.37 ± .05	209 ± 28
8B	Best of All, Sutton	.51	.26	.36 ± .09	204 ± 51
6C	Mass. Field Station, No. 13-1	.43	.28	.36 ± .05	204 ± 28
29	John Baer, Ferry-Morse ..	.48	.29	.35 ± .06	198 ± 34
4	Mass. Field Station x Market Garden Field Station	.58	.24	.35 ± .11	198 ± 62
3	Comet, Perry	.37	.33	.35 ± .02	198 ± 11
37	Bonny Best, Woodruff, F. H	.50	.23	.34 ± .08	192 ± 45
1	Comet, Forbes	.39	.30	.33 ± .04	187 ± 23
42	Early Stone, Harris	.41	.27	.33 ± .05	187 ± 28
41	Rosy Morn, Livingston	.51	.19	.33 ± .10	187 ± 57
83	Red Pear, Eastern States ..	.36	.27	.32 ± .03	181 ± 17
16	Lange's Earliana, Stokes ..	.46	.18	.32 ± .09	181 ± 51
17	Sparke's Earliana, Burpee ..	.44	.24	.32 ± .07	181 ± 40
6D	Mass. Field Station, No. 15-1	.35	.27	.31 ± .03	175 ± 17
86	Red Plum, Comstock-Ferre ..	.33	.29	.31 ± .01	175 ± 56
31	Special Bonny Best Burrell ..	.38	.23	.31 ± .06	175 ± 34
67	Greenhouse Forcing, 6-876, Stokes	.37	.22	.31 ± .05	175 ± 28
38A	Brown's Special (Certi.)	.43	.25	.31 ± .06	175 ± 34
61	Master Marglobe, Woodruff, F. H	.37	.27	.31 ± .03	175 ± 17
47	Stone, Certified, Woodruff, F. H	.40	.21	.31 ± .06	175 ± 34
62A	Marglobe, Abbott and Cobb ..	.38	.24	.31 ± .03	175 ± 17
43	New Stone, Woodruff, F. H. ..	.37	.21	.30 ± .06	170 ± 34
32	Reselected Bonny Best, Comstock-Ferre	.36	.27	.30 ± .04	170 ± 23
6F	Mass. Field Station x Baltimore No. 11—Fall 1935 ..	.43	.18	.30 ± .09	170 ± 51
49	Greater Baltimore, Woodruff, F. H	.38	.24	.30 ± .04	170 ± 23
46	Stone, Livingston	.46	.22	.30 ± .08	170 ± 45
66	Marglobe, Livingston	.39	.22	.30 ± .05	170 ± 28
22	Special Earliana, Platt	.39	.24	.29 ± .05	164 ± 28
9	Lister's Protection, Grey	.42	.23	.29 ± .07	164 ± 40
44	Stone, Burpee	.40	.23	.29 ± .06	164 ± 34
76	Italian Red Pear, Harris	.45	.18	.29 ± .08	164 ± 45
34	Bonny Best, Harris	.32	.22	.29 ± .03	164 ± 17
7	Double Purpose, Forbes	.44	.24	.29 ± .07	164 ± 40
2	Comet, Grey	.38	.22	.29 ± .05	164 ± 28
39	Chalk's Early Jewel, Comstock-Ferre	.40	.19	.29 ± .07	164 ± 40
69	Rutgers, Forbes	.37	.24	.29 ± .04	164 ± 23
33	Bonny Best, Ferry-Morse ..	.36	.21	.29 ± .05	164 ± 28
24	Avon Early, Ferry-Morse ..	.37	.22	.28 ± .05	158 ± 28
65	Marglobe, Forbes	.36	.22	.28 ± .04	158 ± 23

*Standard deviation from the mean.

TABLE I—*Continued*

Plot Number	Variety	Maximum Value (Mg/Gram)	Minimum Value (Mg/Gram)	Mean Value and S. D.* (Mg/Gram)	International Units and S. D.* (Ounce)
18	Sunnybrook, Earliana, Burpee	.41	.23	.28±.06	158±34
40	Chalk's Early Jewel, Grey	.33	.26	.28±.03	158±17
28	John Baer, Eastern States	.37	.19	.28±.06	158±34
56	Markio, Forbes	.34	.23	.28±.03	158±17
15	Earliana, Forbes	.35	.19	.28±.06	158±34
8C	Spring Garden, Abbot and Cobb.	.46	.19	.28±.03	158±17
58	Globe, Livingston	.36	.17	.27±.09	153±51
30	John Baer, Harris	.29	.26	.27±.01	153± 6
21	Selected Earliana, Forbes	.36	.20	.27±.05	153±28
79	Pritchard, Livingston	.41	.19	.27±.07	153±40
8	Belmont Improved, Grey	.35	.20	.27±.05	153±28
73	N. Y. State, Comstock-Ferre	.32	.19	.26±.05	147±28
71	Rutgers, Stokes	.37	.18	.26±.07	147±40
63	Marglobe, Burpee	.30	.19	.26±.05	147±28
50	Indiana, Baltimore, Woodruff, F. H.	.32	.18	.26±.05	147±28
53	Golden Queen, Livingston	.30	.22	.26±.03	147±17
12	Michigan State Forcing, Grand Rapids	.39	.20	.26±.07	147±40
19	Penn. State Earliana, Burpee	.35	.20	.26±.05	147±28
25	Clarks Early Woodruff, F. H.	.30	.21	.26±.04	147±23
45	Stone, Eastern States	.28	.23	.26±.02	147±11
48	Success, Harris	.29	.21	.26±.03	147±17
27	Scarlet Dawn, Platt	.35	.21	.26±.05	147±28
51	Baltimore, Stokes	.33	.23	.26±.04	147±23
38	Super Standard Bonny Best, Stokes	.33	.19	.25±.06	141±34
70	Rutgers, Perry	.38	.19	.25±.06	141±34
36	Bonny Best, Shirley	.29	.23	.25±.03	141±17
64	Marglobe, Eastern States	.30	.21	.25±.03	141±17
10	Grand Rapids, Forcing, Grand Rapids	.35	.21	.25±.05	141±34
35	Bonny Best, Livingston	.31	.20	.25±.04	141±23
26	Scarlet Dawn, Comstock-Ferre	.33	.21	.25±.04	141±23
59	Burpee's Globe, Burpee	.27	.23	.25±.04	141±23
57	Globe, Eastern States	.34	.20	.24±.04	136±23
13	Michigan State Forcing, Ferry-Morse	.29	.20	.24±.04	136±23
82	Red Cherry, Comstock-Ferre	.27	.22	.24±.01	136± 6
65A	Marglobe, Certified, Landreth	.28	.20	.24±.03	136±17
51A	Bloomsdale, Landreth	.31	.18	.24±.04	136±23
55	Grothen's Globe, Ferry-Morse	.33	.16	.23±.05	130±28
55A	Grothen's Red Globe (Certi.), Landreth	.29	.15	.23±.05	130±28
62	Marglobe, Woodruff, F. H.	.28	.20	.23±.03	130±17
23	Avon Early, Burrell	.32	.19	.23±.04	130±23
52	Beauty, Livingston	.24	.22	.23±.01	130± 6

*Standard deviation from the mean.

TABLE I—*Concluded*

Plot Number	Variety	Maximum Value (Mg./Gram)	Minimum Value (Mg./Gram)	Mean Value and S. D.* (Mg./Gram)	International Units and S. D.* (Ounce)
54	Break O'Day, Certified,				
	Woodruff, F. H	.28	.20	.23 ± .03	130 ± 17
78	Pritchard, Eastern States . .	.27	.20	.23 ± .03	130 ± 17
68	Rutgers, Burpee	.30	.17	.22 ± .05	124 ± 28
69A	Rutgers (Certi.), Landreth .	.28	.19	.22 ± .04	124 ± 23
74	Italian Pink Plum, Perry . . .	.30	.15	.22 ± .05	124 ± 28
60	Master Marglobe, Stokes . .	.24	.20	.22 ± .01	124 ± 6
20	Penn State Earlhana, Eastern States	.26	.17	.22 ± .03	124 ± 17
72	N. Y. State, Hart and Vick .	.30	.17	.21 ± .04	119 ± 23
14	Canadian, Harris	.24	.17	.21 ± .03	119 ± 17
77A	Penn State, Landreth	.26	.15	.18 ± .04	102 ± 23
80	Pritchard, Stokes	.18	.09	.13 ± .03	74 ± 17

*Standard deviation from the mean.

ardized dye indicator solution, 2,6-dichlorophenolindophenol, for ascorbic acid. Our unpublished data show that a second extraction of tomato for ascorbic acid increases the total content an average of 10 per cent. To the values obtained on the 98 varieties and strains, 10 per cent was added to the determined amount and the total expressed both in milligrams of ascorbic acid per gram of tomato, and as international units of vitamin C per ounce (Table I).

EFFECT OF VARIETY AND STRAIN ON VITAMIN C CONTENT OF TOMATOES

The results as expressed in Table I show that there is a considerable variation in vitamin C content of tomato varieties. Because of this variation, due consideration should be given to variety when comparing tomatoes to other products containing the antiscorbutic factor. In most cases, Tables I and II indicate the source of the tomato seed.

Von Hahn and Gorbings (8) found that fertilizer constituents influenced the amount of vitamin C in spinach. The differences in ascorbic acid content of tomato varieties cannot be attributed to the fertilizer in this experiment as all varieties received the same nutrients and care. The soil on all experimental plots was of the same type, sandy loam, and it is doubtful that the nutrients absorbed by the plants varied in amount or kind.

Ten varieties contained 200 or more units per ounce. These are truly excellent sources of vitamin C and compare very favorably with oranges or grapefruit. Among the vitamin rich varieties are several promising new strains developed by the Massachusetts Field Experiment Station at Waltham, Massachusetts. Forty-eight varieties or strains, about one-half of the total, yielded between 150 and 200 units per ounce. These tomatoes are also very good sources of vitamin C. A great many of the leading commercial varieties are grouped in the range 140 to 185 units per ounce. Among the low test varieties is Pritchard. Attention is

TABLE II—VITAMIN C CONTENT OF DIFFERENT STRAINS OF THE SAME
SAME VARIETY OF TOMATO

Plot Num- ber	Variety	Maximum Value (Mg/ Gram)	Minimum Value (Mg/ Gram)	Mean Value and S. D. * (Mg/ Gram)	International Units and S. D. * (Ounce)
6E	Greenhouse No. 9-1936	.50	.41	.44 ± .03	249 ± 17
6	Mass. Field Station, No. 7-1	.58	.29	.41 ± .09	232 ± 57
5	Mass. Field Station, No. 2-1	.50	.30	.39 ± .08	221 ± 45
6B	Mass. Field Station, No. 11-1	.54	.31	.39 ± .07	221 ± 40
6A	Mass. Field Station, No. 8-1	.49	.29	.37 ± .05	209 ± 28
6C	Mass. Field Station, No. 13-1	.43	.28	.36 ± .05	204 ± 28
4	Mass. Field Station x Mar- ket Garden Field Station	.58	.24	.35 ± .11	198 ± 62
6D	Mass. Field Station, No. 15-1	.35	.27	.31 ± .03	175 ± 17
6F	Mass. Field Station x Balti- more, No. 11—Fall 1935	.43	.18	.30 ± .09	170 ± 51
	Average for all strains	—	—	.37 ± .08	209 ± 45
3	Comet, Perry.	.37	.33	.35 ± .02	198 ± 11
1	Comet, Forbes...	.39	.30	.33 ± .04	187 ± 23
2	Comet, Grey	.38	.22	.29 ± .05	164 ± 28
	Average for all strains	—	—	.32 ± .04	181 ± 23
29	John Baer, Ferry-Morse	.48	.29	.35 ± .06	198 ± 34
28	John Baer, Eastern States	.37	.19	.28 ± .06	158 ± 34
30	John Baer, Harris	.29	.26	.27 ± .01	153 ± 6
	Average for all strains	—	—	.31 ± .06	175 ± 34
47	Stone (Certi.), Woodruff, F. H.	.39	.21	.31 ± .06	175 ± 34
46	Stone, Livingston	.46	.22	.30 ± .08	170 ± 45
44	Stone, Burpee	.40	.23	.29 ± .06	164 ± 34
45	Stone, Eastern States	.28	.23	.26 ± .02	147 ± 11
	Average for all strains	—	—	.29 ± .06	164 ± 34
37	Bonny Best, Woodruff, F. H.	.50	.23	.34 ± .08	192 ± 45
31	Special Bonny Best, Burrell	.38	.23	.31 ± .06	175 ± 34
32	Resclected Bonny Best, Comstock-Ferre.	.36	.27	.30 ± .04	170 ± 23
34	Bonny Best, Harris	.32	.22	.29 ± .03	164 ± 17
33	Bonny Best, Ferry-Morse	.36	.21	.29 ± .05	164 ± 28
38	Super Standard Bonny Best, Stokes	.33	.19	.25 ± .06	141 ± 34
36	Bonny Best, Shirley	.29	.23	.25 ± .03	141 ± 17
35	Bonny Best, Livingston	.31	.20	.25 ± .04	141 ± 23
	Average for all strains	—	—	.29 ± .05	164 ± 28
61	Master Marglobe, Wood- ruff, F. H.	.37	.27	.31 ± .03	175 ± 17
62A	Marglobe, Abbott and Cobb	.38	.24	.31 ± .03	175 ± 17
66	Marglobe, Livingston	.39	.22	.30 ± .05	170 ± 28
65	Marglobe, Forbes	.36	.22	.28 ± .04	158 ± 23
63	Marglobe, Burpee	.30	.19	.26 ± .05	147 ± 28
64	Marglobe, Eastern States	.30	.21	.25 ± .03	141 ± 17

*Standard deviation from the mean.

TABLE II—*Concluded*

Plot Number	Variety	Maximum Value (Mg./Gram)	Minimum Value (Mg./Gram)	Mean Value and S. D.* (Mg./Gram)	International Units and S. D.* (Ounce)
65A	Marglobe (Certi.), Landreth	.28	.20	.24 ± .03	136 ± 17
62	Marglobe, Woodruff, F. H. . .	.28	.20	.23 ± .03	130 ± 17
60	Master Marglobe, Stokes . . .	.24	.20	.22 ± .01	124 ± 6
	Average for all strains . . .	—	—	.27 ± .04	153 ± 23
58	Globe, Livingston	.36	.17	.27 ± .09	153 ± 51
59	Burpee's Globe, Burpee . . .	.27	.23	.25 ± .04	141 ± 23
57	Globe, Eastern States	.34	.20	.24 ± .04	136 ± 23
	Average for all strains . . .	—	—	.26 ± .05	147 ± 28
69	Rutgers, Forbes	.37	.24	.29 ± .04	164 ± 23
71	Rutgers, Stokes	.37	.18	.26 ± .07	147 ± 40
70	Rutgers, Perry	.38	.19	.25 ± .06	141 ± 34
68	Rutgers, Burpee	.30	.17	.22 ± .05	124 ± 28
69A	Rutgers (Certi.), Landreth .	.28	.19	.22 ± .04	124 ± 23
	Average for all strains . . .	—	—	.25 ± .05	141 ± 28
79	Pritchard, Livingston	.41	.19	.27 ± .07	153 ± 40
78	Pritchard, Eastern States . .	.27	.20	.23 ± .03	130 ± 17
80	Pritchard, Stokes	.18	.09	.13 ± .03	74 ± 17
	Average for all strains . . .	—	—	.21 ± .08	119 ± 45

*Standard deviation from the mean.

called to variations found among different fruits of the same variety. Too definite conclusions cannot be drawn because of this variation. It is possible that a tomato plant under other conditions might produce different results.

Table II is a recapitulation of a part of the data in Table I. Here the strains of each important variety are collected for comparison. The data show some similarity between strains of each variety, the variations being not too significant with only one season's samples.

The grouping of varieties by genetic groups aids in evaluating them as carriers of vitamin C. The nine Massachusetts Field Station strains are consistently high, averaging 207 units per ounce. It appears that by suitable selection and breeding, strains of tomatoes high in vitamin C can be obtained. Undoubtedly, it is more than a coincidence that all three of the Comet strains, seeds of which were grown in different parts of the United States, show a high vitamin C value. With a little care the canners of tomatoes and tomato juice should be able to select and perfect improved strains of tomatoes of higher vitamin C potency than are now grown commercially.

EFFECT OF SIZE OF TOMATO ON VITAMIN C CONTENT

McHenry and Graham (4) found that there is an inverse relationship between size and vitamin C content of ripe tomatoes. Of the common commercial varieties and strains of tomatoes that were grown and

TABLE III—EFFECT OF STAGE OF MATURITY ON ASCORBIC ACID CONTENT OF TOMATOES

Variety	Sample Number	Hard Green		Half Ripe		Fully Ripe	
		Ascorbic Acid (Mg. Gram)	International Units Vitamin C (Ounce)	Ascorbic Acid (Mg. Gram)	International Units Vitamin C (Ounce)	Ascorbic Acid (Mg. Gram)	International Units Vitamin C (Ounce)
John Baer, Harris	1	.28	—	.31	—	.29	—
John Baer, Harris	2	.17	—	.18	—	.26	—
John Baer, Harris	3	.28	—	.35	—	.26	—
Average	—	.23	130	.28	158	.27	153
Beauty, Livingston	1	.25	—	.35	—	.22	—
Beauty, Livingston	2	.16	—	.29	—	.22	—
Beauty, Livingston	3	.24	—	.22	—	.24	—
Average	—	.22	124	.24	136	.23	130
Stone, Burpee	1	.32	—	.27	—	.25	—
Stone, Burpee	2	.38	—	.25	—	.40	—
Stone, Burpee	3	.27	—	.26	—	.24	—
Average	—	.32	181	.26	146	.29	164
Clark's Early, Woodruff	1	.19	—	.26	—	.30	—
Clark's Early, Woodruff	2	.22	—	.21	—	.21	—
Clark's Early, Woodruff	3	.24	—	.31	—	.27	—
Average	—	.22	124	.26	147	.26	147
Success, Harris	1	.36	—	.26	—	.29	—
Success, Harris	2	.26	—	.21	—	.21	—
Success, Harris	3	.37	—	.31	—	.28	—
Average	—	.33	187	.26	147	.26	147
Comet, Perry	1	.27	—	.45	—	.37	—
Comet, Perry	2	.39	—	.30	—	.33	—
Comet, Perry	3	.33	—	.41	—	.35	—
Average	—	.33	187	.39	221	.35	198

examined at this station, no correlation could be found between size and vitamin C content. The largest and the smallest tomato fruit of each variety and strain were compared. In 48 cases the largest tomato had a greater amount of ascorbic acid per gram of tomato than the smallest one, the average per cent difference of vitamin C content being 40.3. In the remaining 43 cases the smallest tomato had the greater amount of vitamin C per unit of weight, the average per cent difference in ascorbic acid content being 18.9.

EFFECT OF MATURITY ON VITAMIN C CONTENT

Although all tomatoes selected for the determination of vitamin C in tomato varieties were harvested when considered to be fully ripe, there was difficulty in estimating the same degree of ripeness for each selection. To ascertain whether the stage of maturity influenced the amount of vitamin C in the varieties determined, six varieties were examined for vitamin C when green and hard, but full grown, when half-ripe, and when fully ripe. The results are shown in Table III. Fruits at the different stages of development were picked from the same plants.

Six to eight tomatoes were selected, typical of the degree of maturity to be tested. Three composite samples of from 15 to 20 grams were prepared for the dye titration method of determining vitamin C. The data show no consistent increase in the vitamin C content of tomatoes during the three stages of maturity studied and therefore it cannot be considered that the degree of ripeness influenced the variation of vitamin C content among tomato strains and varieties shown in Tables I and II.

EFFECT OF STORAGE ON VITAMIN C CONTENT

The samples of tomato varieties and strains in Tables I and II were titrated for vitamin C as rapidly as possible after the fruit had been harvested. No samples were stored overnight. However, to determine the effect of length of storage at room temperature on the vitamin C content of fully ripe tomatoes, an experiment using two varieties was arranged. The results given in Table IV, show that up to 240 hours of storage (10 days) that there is no apparent loss in vitamin C. Hence, ripe tomatoes may be stored for several days or even weeks after harvesting with little loss of vitamin C content.

Green Marglobe tomatoes shipped from Florida in January were partly colored upon arrival in Amherst. Some were wrapped in parchment wraps. Vitamin C examinations showed wrapped and unwrapped, fully and partly ripe fruit had essentially the same vitamin C content, *e.g.*, 91 to 97 units per ounce. This value is considerably less than was found in Northern grown Marglobes.

SUMMARY

Ninety-eight distinct varieties or strains of tomatoes were grown under constant field conditions and compared as to vitamin C content. The tomato shows considerable variation with values ranging from a

TABLE IV.—EFFECT OF LENGTH OF STORAGE OF FULLY RIPE TOMATOES AT ROOM TEMPERATURE ON VITAMIN C CONTENT

Variety	Hours Storage	Sample Number					Average International Units Vitamin C (Ounce)
		1	2	3	4	Average	
		Ascorbic Acid (Mg./Gram)	Ascorbic Acid (Mg./Gram)	Ascorbic Acid (Mg./Gram)	Ascorbic Acid (Mg./Gram)	Ascorbic Acid (Mg./Gram)	
Marglobe	Fresh	.29	.27	.24	.30	.27	153
Marglobe.	20	.25	.24	.16	.28	.23	130
Marglobe.	44	.38	.30	—	—	.24	136
Marglobe.	68	.24	.26	.28	.20	.25	141
Marglobe.	92	.35	.31	.24	.41	.33	187
Marglobe.	140	.22	.27	.22	.20	.23	130
Marglobe.	190	.32	.21	.28	.20	.25	141
Marglobe.	240	.19	.28	.22	.32	.25	141
No. 6E—Greenhouse							
No. 9—1936	2	.42	.41	.42	.50	.44	249
No. 6E—Greenhouse							
No. 9—1936	48	.45	.34	.30	.37	.37	209
No. 6E—Greenhouse							
No. 9—1936	96	.38	.38	.38	.52	.42	238
No. 6E—Greenhouse							
No. 9—1936	168	.33	.36	.30	.36	.34	192
No. 6E—Greenhouse							
No. 9—1936.	216	.40	.30	.25	.51	.37	209

maximum of 249 units per ounce to a minimum of only 74 units. By application of an arbitrary scale of vitamin C evaluation, varieties of good vitamin C potency should exceed 150 units per ounce. By selection it would seem entirely possible to considerably increase the vitamin C content of the tomato crop.

There were marked differences in vitamin C content among different strains of the same variety. The various Massachusetts Field Station varieties ranked highest as a group with Comet second, and John Baer, Stone and Bonny Best all above 160 units per ounce. Both Pritchard and Rutgers varieties gave relatively low results.

No correlation was found between size of a tomato and its vitamin C content. Using six varieties of tomatoes, results show that degree of ripeness has no significant effect upon the vitamin C content of the tomato. Storage of ripe tomatoes of two varieties for 10 days at room temperature had no effect on the vitamin C content.

A selection and breeding program designed to increase the vitamin C content of tomatoes may be readily carried on by the use of the rapid dye titration technic as a check.

From the data on storage tests, it would seem that the vitamin C content of tomatoes is not seriously affected during shipment, in markets or at canneries, so long as the fruits remain firm and sound.

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. The Stability of Vitamin C in Sweet Corn to Shipping, Freezing and Canning

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ABSTRACT

This paper will be published in full in *Food Research*.

ALTHOUGH satisfactory checks were obtained on fresh raw and fresh cooked sweet corn between the dye titration and the animal bioassay methods the dye method gave much higher results than did the animal bioassay method on canned and frozen sweet corn. The oxidation of ascorbic acid while the sweet corn is exposed to air in the feeding cups is a source of error in the assay method.

There is only a small loss in vitamin C content of sweet corn which has been frozen. Canned sweet corn with the exception of vacuum canning, shows on the average an ascorbic acid content about 10 per cent less than the average fresh sweet corn; vacuum canned whole kernel sweet corn showed as high vitamin C content as fresh sweet corn. Sweet corn shipped cold storage retains its original content of vitamin C to a large extent.

The ascorbic acid content of various brands of canned sweet corn showed considerable variation but, in general, retained the original content very well. Whole kernel corn had a higher ascorbic acid content than cream-style. Hulled corn (lye hominy) was a poor source of vitamin C.

Raw fresh sweet corn and good quality market sweet corn contain about the same amount of ascorbic acid. Heating sweet corn for eating destroys 7 to 10 per cent of the ascorbic acid. Sweet corn stored at room temperature and at refrigerator temperatures, lost almost no ascorbic acid the first day; only about 20 per cent after 3 days; and 50 per cent after 4 days. Negligible loss of vitamin C occurs in storage at -10 degrees F. Less than 5 per cent loss of ascorbic acid occurs in frozen sweet corn defrosted for 24 hours. There is little change in C vitamin content of sweet corn from the first to the end of the season. There is a general loss during maturation.

Raw, fresh cooked (cut or cob), frozen and whole-grain canned sweet corn are all moderately good sources of vitamin C *i.e.*, 40 to 50 international units per ounce. Cream-style canned corn is a little lower than whole kernel.

It is significant that little loss in vitamin C occurs after picking and storage in the husk for a few days. Similarly frozen corn can be defrosted and canned corn kept in the refrigerator for several hours after opening without appreciable loss of vitamin C.

Comparative Tests of Seed Drills Used in Vegetable Production

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THE developing of effective garden tools has not kept pace with our scientific knowledge of the function of this type of machinery. It has been known for some time that fertilizing materials, to be most effective, should be placed near the seed or transplanted seedlings but not in direct contact with them. Although several attempts have been made by manufacturers to perfect hand operated seed drills that will sow the seed and at the same time effectively place the fertilizing materials, these attempts have been, as a rule, unsuccessful.

The research reported herewith was started to determine the advantages and disadvantages of each of the several mechanical features of a number of drills preparatory to the development of more effective tools for planting and fertilizing vegetable crops.

RESULTS

As several types of seeders were used a brief description of each is necessary to be able to understand the comparative results obtained. The seeding units and fertilizing units in these planters are entirely separate. Some advantages and disadvantages of these tools are listed in order to picture more clearly their relative values as planters.

Cylinders with cup-like depressions large enough to hold one seed are used in planter number one. The depressions in each cylinder are all the same size but they may be used frequently for planting seeds of different vegetables which are nearly equal in size. Different spacing of seeds may be obtained quickly and easily by reversing the gears of the chain drive connecting the front wheel and the cylinder shaft. The cylinder rotates in the seed hopper. A brush close to the cylinder prevents an excess of seed from going through in each depression. Covering is effected by a one piece casting which drags the soil in from both sides. This planter with its cylinder type of feed provides a more accurate placement of seeds in the row (See Table I). The beans and corn planted with it came up more evenly spaced than with any other planter, Fig. 1. The depth of planting is easily changed by a vertical adjustment of the shoe. The planter places the seed in a narrow row which is easily weeded. The fertilizer attachment is placed directly behind the seeder unit and is driven by a chain drive from the front wheel. A cup or cone in the bottom of the fertilizer hopper takes the fertilizer out of the hopper which rotates around the cup. The amount applied is varied by changing the size of the cup. Most of the fertilizer is placed in direct contact with the seed. The flow of fertilizer may be stopped by removing the pin from the driving clutch. The planter including fertilizer attachment is easy to push and handles well.

Planter number two consists of a seeder unit only. The amount of seed sown depends on the size of the hole in the bottom of the

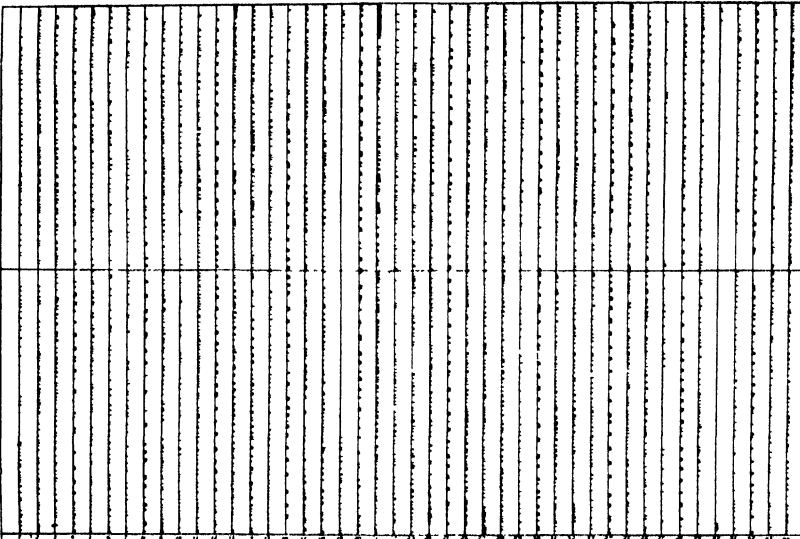
TABLE I—COMPARISON OF THE SEEDING RATE AND FERTILIZER DISTRIBUTION OF THE SIX PLANTERS USED (50 FOOT ROWS)

Seeder Number	Number of Seeds Sown in the Replications							
	First Plot				Second Plot			
1 Beans Corn	177 108	157 130	170 125	183 166	195 231	170 156	193 157	188 95
2 Beans Corn	108 288	101 236	152 —	134 —	227 105	224 98	224 —	— —
3 Beans Corn	33 201	39 168	31 —	33 —	85 73	92 58	90 81	107 40
4 Beans Corn	195 150	170 291	193 251	188 227	122 120	87 120	129 104	117 134
5 Beans Corn	208 254	151 219	125 303	167 332	193 375	172 361	144 34	120 246
6 Beans Corn	117 215	107 257	151 206	95 305	93 293	104 318	196 259	157 20

	Ounces of Fertilizer Sown in the Replications							
	Sodium Nitrate				2-12 6			
1 Beans Corn	9 6.5	9 7	14 8	9 8	9 7	9 7	9 7	10 9
2 Beans Corn	— 0	— 0	— 0	— 0	0 —	— 0	— 0	— 0
3 Beans Corn	— 0	— 0	— 0	— 0	— 0	— 0	— 0	— 0
4 Beans Corn	10 11	9 11	6 12	10 12	7 8.5	7 10	8 13	7 8.5
5 Beans Corn	4 7.5	6.5 7	10 7	6.5 8	8 12.5	9 11	8 12.5	9 12
6 Beans Corn	8 7	7 7.5	9 7.5	12 9.0	9 11	13 8.5	11 12	8 11

hopper which may be opened or closed by a sliding gate. A brush driven by a chain from the front wheel agitates the seed in the hopper and forces it through the hole in the bottom of the hopper. The shoe which may be adjusted vertically cannot be rigidly held in place. The tool can be converted into a garden cultivator and used as a one or two wheel cultivator. The planter is light in weight, easy to push, and it handles easily.

Planter number three has a cylinder type of feed not as accurate as number one because of rough cylinders. The cylinder is turned by a chain drive from the front wheel, the speed of the cylinder being changed by reversing the gears. Four different cylinders plant all seeds



ROW NUMBER	SEEDER NUMBER	KIND OF FERTILIZER	ROW NUMBER	SEEDER NUMBER	KIND OF FERTILIZER
1 and 22	1	NONE	12 and 35	9	8 - 12-6
7 and 23	2	NONE	13 and 35	5	8 - 12-6
9 and 24	3	NONE	14 and 36	6	2 - 12-6
6 and 25	4	NONE	15 and 37	1	20% SUPERPHOSPHATE
5 and 26	5	NONE	16 and 38	4	20% SUPERPHOSPHATE
8 and 27	6	NONE	17 and 39	2	20% SUPERPHOSPHATE
7 and 28	7	NITRATE OF SODA	18 and 40	6	20% SUPERPHOSPHATE
6 and 30	8	NITRATE OF SODA	19 and 41	1	BONE MEAL
8 and 31	5	NITRATE OF SODA	20 and 42	4	BONE MEAL
10 and 32	6	NITRATE OF SODA	21 and 43	2	BONE MEAL
11 and 33	1	8 - 12-6	22 and 44	6	BONE MEAL

A COMPARISON OF THE APPROXIMATE LOCATION OF CORN SEEDLINGS IN A FERTILIZER PLACEMENT TEST WITH VARIOUS GARDEN SEEDERS

CMA 1936

FIG. 1. A comparison of the approximate location of corn seedlings in a fertilizer placement test with various garden seeders.

thus making accurate sowing almost impossible. The front wheel is small and narrow which sinks in loose soil and may even become buried. The shoe of the planter is easily adjusted vertically. The planter is pushed easily on a hard seed-bed but is hard to push on loose soil.

Seeder number four is a heavy planter having a cylinder type of feed. The cylinder has a slotted circumference, each slot carrying one or more seeds. A brush keeps excess seed from going through into each slot. The amount of seed may be varied by changing the cylinder speed and by raising the brush from the cylinder. A set of cylinders for sowing various seeds is furnished with the planter. The seeder and fertilizer mechanism are driven by the same chain from the front wheel. The spacing of the seed is changed by changing gears on the front wheel and the cylinder shaft. The depth of planting is regulated by adjusting the shoe vertically. The shoe is wide which makes the planter difficult to push and also sows a wide row of seed. The fertilizer is sown by a cylinder type of feed. The amount of fertilizer is varied by changing the number and slotting of fertilizer cylinders and by changing the speed of the cylinders. It frequently takes considerable time to

get the right combination of gears on the chain drive to sow the correct amount of seed and fertilizer. The fertilizer frequently leaks past the fertilizer cylinder when the cylinder slot is opposite the lower edge of the hopper, where the fertilizer is expelled, and also between the fertilizer cylinders when different numbers of slots are used in the cylinders at the bottom of the hopper. This planter tends to place the fertilizer in hills. The fertilizer shoes are constructed so that the device for vertical adjustment of the shoes is so near the surface of the ground that soil is pushed ahead of the shoe adjustment, making it difficult to push the planter. Some parts of the planter are made of cast iron and some difficulty was experienced because these parts were broken. The handles are made of steel and have rubber grips which, when setting in the sun, become uncomfortably warm.

Planter number five has a seeding unit similar to number two. The amount of seed is varied by opening or closing a sliding gate thus changing the size of the opening through which the seed flows. The agitator or brush in the seed hopper is driven by a chain from the front wheels and it forces the seed through the hole in the bottom of the hopper. The planter has a checking mechanism which may be used at any time, although it is not very substantial. The vertical adjustment of the shoe is adequate but will not remain in position. The fertilizer unit is simply constructed, being located directly above the axle between the two front wheels. The unit consists of a long toothed gear which forces the fertilizer out through a slot the size of which regulates the amount of fertilizer sown. The agitator drives this gear and a set of bevel gears drive the agitator from the axle. The fertilizer is sown in bands beside and below the seed and the exact distance may be regulated by the proper adjustments. The fertilizer is carried from the hopper to the shoes by flexible coiled wire tubes. In two instances the fertilizer corroded the metal of the gear in the fertilizer hopper and "froze" the bearing. Fertilizer may run through the gear and the slot when the fertilizer slot is wide open even though the planter is standing still. The fertilizer shoes are in front of the planter and in rough ground they may make the planter hard to handle. The wheels are narrow and tend to sink in on muck or other loose soil. The two wheels at the side make it more difficult to keep the planter on the row than if it had a single front wheel. The planter is easier to push than number four and harder than number one.

Planter number six is of the round hole type of seeder, with a large number of holes of graduated sizes on three different plates. This seems to be more accurate than the variable sized hole planters (Fig. 1). The amount of seed sown depends on the size of hole used in the hopper. An agitator forces the seed through the hole. The shoe is easily adjusted vertically and remains in position. The fertilizer attachment is not very satisfactory. It consists of a hopper which is rigidly supported above the pan or plate. The pan is agitated horizontally and feeds the fertilizer through a hole the size of which regulates the amount of fertilizer sown. The height of the hopper above the pan also regulates the amount sown. A cam on the rear wheel agitates the pan. The fertilizer is applied on both sides of the row on top of the seed and

slightly mixed with the soil directly over the seed. The amount of application is difficult to regulate. As the attachment is driven by a cam from the back wheel it is almost impossible to sow fertilizer on very loose soil without the wheel slipping and disturbing the seed and reducing the amount of fertilizer sown. The planter pushes easily and handles nicely except for trouble with fertilizer attachment.

These planters place the fertilizer in different positions relative to the seed so the different results indicated in Tables II and III are to be expected.

TABLE II—REDUCTION OR INCREASE IN PER CENT OF STAND OF BEANS IN FERTILIZER TEST PLOTS IN COMPARISON WITH CHECK PLOT WITHOUT FERTILIZER

Seeder Number	Sodium Nitrate	2-12-6 Mixed Fertilizer	20 Per Cent Superphosphate	2-24-0 Bone Meal
1	-33.2±10.7	-18.8±10.7	+7.7±10.7	-7.2±10.7
4	+4.2±10.7	-3.3±10.7	+4.7±10.7	-2.7±10.7
5	-19.9±10.7	-9.6±10.7	-7.8±10.7	-12.8±10.7
6	-17.7±10.7	-18.0±10.7	-3.4±10.7	-13.0±10.7

TABLE III—REDUCTION OR INCREASE IN PER CENT OF STAND OF CORN IN FERTILIZER TEST PLOTS IN COMPARISON WITH CHECK PLOT WITHOUT FERTILIZER

Seeder Number	Sodium Nitrate	2-12-6 Mixed Fertilizer	20 Per Cent Superphosphate	2-24-0 Bone Meal
1	-29.6±13.3	-16.5±13.3	-38.1±13.3	-10.5±13.3
4	-19.0±13.3	-2.6±13.3	-8.7±13.3	- .5±13.3
5	+8.3±13.3	+2.0±13.3	-3.3±13.3	+3.3±13.3
6	-19.3±13.3	-7.7±13.3	+2.8±13.3	+3.1±13.3

The standard errors were figured by Fisher's method of statistical analysis as modified by Snedecor (1).

Planter number one placed most of the fertilizer in contact with the seed and it is not surprising that the reduction in stand is highly significant in both beans and corn when sodium nitrate fertilizer is used.

IMPROVED FERTILIZER DISTRIBUTOR RESULTS

Most of the tests were made early in the season but in later tests seeder number one was changed so that fertilizer was applied below the seed on each side of the row. Using planter number five as a check in a test with peas in the fall the improved planter gave a 6 per cent reduction in per cent of stand, while the original planter gave a 38 per cent reduction in stand with sodium nitrate. With a 2-12-6 fertilizer the original gave a 9.9 per cent reduction in per cent of stand while the improved model increased the stand 11.5 per cent. Additional changes are being made as a result of these tests which we hope will provide even more effective fertilizer placement.

Thanks are due the Empire Plow Company, Cleveland, Ohio, for financing this project and for much valuable assistance and many helpful suggestions.

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The Effect of Various Dusts Upon the Rate of Seeding of Various Vegetable Seeds

By O. H. PEARSON, *Springfield, Mass.*

THERE has recently been considerable interest among growers, plant pathologists and seedsmen regarding the use of various dusts applied to the seed to control pre-emergence damping off. On a large scale, seeds of the cereals have been treated for many years with copper carbonate. Recently it has been recommended that pea seed for the canning crop be treated with red copper oxide for the control of damping off. The methods of application and sowing by machines have been studied and the factors influencing their success described (1, 2). In the past 3 or 4 years dust treatments of seed have been recommended for a number of vegetables commonly grown for market. These dust treatments usually consist of cuprous oxide, zinc oxide containing some zinc hydroxide (Vasco 4) (3), organic mercury compounds such as Semesan and Semesan Jr., and other finely divided dusts. To be acceptable for such use these dusts must be ground to pass through at least a 325 per inch screen.

Remarkable increases have been secured in stand and yield by the use of such dust treatment. Under laboratory conditions where comparable volumes or weights of treated and untreated seed are used these results are undoubtedly due to the beneficial effects of the seed treatment. Under field conditions it might be possible to ascribe these beneficial results to differences in seeding rates. Hulbert and Whitney (2) and Arnold and Horsfall (1) have shown that these dusts affect the rate of seeding of peas and that harmful effects due to extra friction upon the machinery used in drilling the seeds and injury to the seeds due to the higher pressures developed by such machinery when drilling dusted seed could be avoided by the use of graphite. Consequently it would seem advisable to determine what effect, if any, these dusts would have upon the rate of seeding of vegetables planted by the gravity flow type of equipment such as market gardeners use.

A simple set-up was devised using a common gravity type of seeder in which an agitator prevents bridging of the seed over a variable orifice through which the seed falls. This was driven by a quarter horse power motor at such speed that the large drive wheel made 26.6 revolutions per minute or a speed of 1.22 miles per hour. Translated into rates of seeding this would mean that one seeder would be able to plant an acre of 15 inch rows in 5½ hours. The number of revolutions was determined by a counter connected with the main drive wheel. The covering wheel was driven by an eccentric which ran a little faster than the main wheel so as to shake the machine and to avoid bridging effects in the hopper. The procedure was to fill the hopper approximately a third full of the seed to be tested and run the machine for 100 revolutions, catching the discharged seed in a pan beneath the hopper and weighing this upon a spring scale. Each test was replicated five times and the results always showed a duplication within 2 per cent. Two settings were used for each seed, one approximately the correct setting as indicated by the manufacturer and the other, several notches smaller. The tests reported here were made

TABLE I—EFFECT OF VARIOUS DUSTS UPON THE PASSAGE OF VARIOUS VEGETABLE SEEDS THROUGH A PLANET JR. NO. 300 SEEDER (SPEED, 110 FEET PER MINUTE)

Kind of Seed	Setting	Grams of Seed Delivered per 100 Rev.					Change Due to Dust (Per Cent)	Change Due to Dust + Graphite (Per Cent)
		Check	Cu ₂ O	Cu ₂ O + Graphite	Zn O	Zn + Graphite		
Spinach.....	12	80	90	100	—	—	+12.5	+25
	8	33	36	42	—	—	+9	+27
Kohlrabi.....	6	56	—	—	43	52	-23.2	+7.1
	3	17	—	—	15	16	-11.7	-5.8
Chinese Cabbage....	5	39	—	—	32	43	-17.9	+10.2
	2	14	—	—	13	19	-7.1	+35.7
Radish.....	13	127	—	—	112	129	-11.8	+1.5
	9	56	—	—	52	60	-7.1	+7.1
Lettuce.....	12	48	—	—	42	43	-12.5	-10.4
	8	21	—	—	17	16	-19	-23.8
Carrot.....	8	36	—	—	39	24	+8.3	-33.3
	5	18	—	—	19	11	+5.5	-38.8
Beets.....	22	54	56	57	—	—	+3.7	+5.5
	18	24	25	21	—	—	+4	-12.5
Tomato.....	12	21	24	21	—	—	+14.2	-27.2
	8	11	13	8	—	—	+18.1	—
Parsnip.....	29	52	—	—	64	—	+23	—
	26	36	—	—	38.5	—	+6.94	—
Celery.....	3	21	—	—	18	26	-14.2	+23.8
	1	11	—	—	9	16.7	-18.1	+51.81
Pea—Little Marvel	38	1260	1392	1632	—	—	+10.4	+21.5
	34	320	384	408	—	—	+20	+27.5
Hundredfold	38	1336	1280	1620	—	—	-4.1	+21.2
	34	360	356	456	—	—	-1.1	+26.6
Alderman.....	38	1500	1420	1680	—	—	-5.3	+12
	34	376	408	464	—	—	+8.5	+23.4

during January and February 1936 using materials commonly employed in vegetable seed treatment. The cuprous oxide was a dry powder ground to pass a 325 mesh screen, zinc oxide was pure grade, finely ground, and graphite was the same material as described by Arnold and Horsfall (1). The vegetable varieties used were those commonly planted by drills and varied in type of seed coat as well as size and weight. The results are presented in Table I.

From the results obtained it appears that the application of dust on certain vegetable seeds may increase the rate of seeding as much as 23 per cent in some cases, in others it may decrease the rate fully as much. The direction and amount of change appear to be correlated with the surface of the seed and to its density. Thus seeds which have smooth coats (Kohlrabi, Chinese Cabbage, Radish, Lettuce) are retarded by the application of dust. Arnold and Horsfall (1) report that tests of their own and of others, with similar equipment, on smooth seeded plants (cabbage, wheat and peas) show a decrease in seeding rate of as much as 27 per cent. However, rough coated seed, such as spinach, carrot, beet, tomato, parsnip and small seeded peas, show an appreciable acceleration of seeding rate due to the dust, as with tomato, parsnip and small seeded peas. It may be that the weight or kind of dust has an influence, since most of those treated with cuprous oxide showed an increase in rate whereas those with zinc dust showed a decrease, but this trend is not uniform. Celery seed behaves differently than other items in its class of treatment. This possibly is because of the different surface-volume ratio.

It has been found by the previously quoted authors that the application of graphite dust to pea seed restores the seeding rate to practically normal. Similar treatment of other seeds did not give consistent results. Graphite dust actually depressed the rate of seeding of carrot and lettuce seed. In smooth seeded types, and even in the wrinkled peas, graphite dust corrected the effect of the cuprous oxide or zinc oxide and actually increased the rate of seeding above that of untreated seed. This effect cannot be as closely correlated to type of seed coat as when dust alone is used, nor to the surface-volume ratio. Lettuce seed is smooth coated, but the rate of seeding was unaffected by the addition of graphite. The rate of discharge of brassica seed, also smooth coated, was greatly increased by the use of graphite. Celery seed also flowed much more freely when lubricated. Carrot, on the other hand, showed a considerable decrease in rate due to graphite. Excepting carrot and lettuce, graphite either corrected the retarding effect of other dusts, or accelerated their flow. It would appear that the rate of seeding of vegetable seeds treated with finely ground dusts varies, and that growers must be cautioned to adjust planters to retain a normal rate of seeding.

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Transplant Responses

By VINCENT E. IVERSON, *Montana State College, Bozeman, Mont.*

EXPERIMENTS are now in progress at the Montana State Experiment Station to determine the effects of various methods of handling transplants, from the seedling stage to the time of field planting, upon the early and later development of the plant with an effort to develop an efficient, practical technique in vegetable transplant culture. At the present time the data indicate a significant relationship between various methods of transplant handling and crop performance. The effects of fertilizers and chemicals alone and in combination, together with the effects of temperature, age of the transplant and the type and size of the container for the growing of the transplant have been studied in relation to the development of the following normally transplanted vegetable crops: tomatoes, peppers, onions, head lettuce, celery and cabbage. Because the extensive data are not as yet entirely analyzed, this paper is limited to a consideration of a few of the outstanding differences which have been observed together with a few possible theoretical explanations.

The fertilizers and chemicals used on each of the types of vegetable transplants were as follows: nitrogen, phosphorus, potassium permanganate and dextrose in the following amounts per flat (size 12 x 20 x 3 inches), nitrogen (12 grams sulphate of ammonia plus 6 grams nitrate of soda), phosphorus, (18 grams superphosphate, 16 per cent), potassium permanganate, (4 grams commercial), dextrose (8 grams). The materials were applied singly and also in combinations of two. The applications in all cases were made on the surface of the soil at the time of pricking-off from the seedling flats except in the series of onions where the plants were not pricked off but which received the fertilizer applications shortly after the seed germinated. The soil mixture consisted of one part manure, one part sand, and two parts loam with a pH of 7.65. The responses of the several vegetable types to the various treatments were generally quite similar.

NITROGEN

In the case of onions a distinct response to nitrogen was noted. Nitrogen applied during the transplant stage resulted in the development of a large, succulent top growth of a dark green color and a distinct tendency to lodge. The plants developed a small apparently inefficient root system with few secondary rootlets. The nitrogen treatments in the amounts used appeared to have a slightly toxic effect upon the root system of the transplants. This injurious effect was noted on all onion transplants but to a greater extent on the Mountain Danvers than on the Sweet Spanish variety. Varietal difference was also noted in the ability of the plants to survive transplanting. Due to extreme succulence, as well as the other effects mentioned, plants receiving nitrogen were in a much poorer condition after field planting than plants produced under any of the other treatments. This effect was most pronounced in the Mountain Danvers variety. Nitrogen application to cabbage, lettuce and celery transplants resulted in a

somewhat similar response although to a lesser degree than with the onion transplants. Nitrogen applications to tomato transplants caused a rapid, succulent top development of a dark green color without a correspondingly rapid root development. The ratio of root to top was considerably less than with any other fertilizer or chemical treatment. In the case of the tomato, the plants were handled in pots of different types and different sizes, the fertilizer applications being relatively the same per unit of soil as with the flat treatments. With these pot treatments, nitrogen applications in most cases delayed the development of flowers and fruit except when used in combination with potassium permanganate which seemed to offset the effects of delayed maturity.

A combination of nitrogen and potassium permanganate increased the early yield of No. 1 tomatoes as much as 370 per cent over the check and 78 per cent over the nitrogen treatment alone in the 4-inch paper pots. Where the 4-inch clay pots were used, potassium permanganate with nitrogen resulted in an increase of 86 per cent in early No. 1 yield whereas nitrogen alone resulted in actual decreased yields and a marked delay in maturity. Due to the action of cellulose digesting micro-organisms on the paper pots a nitrogen deficiency probably resulted. The available nitrogen was used up by the micro-organisms and thus when nitrogen was supplied, a marked increase in yield resulted. With the clay pot treatments, however, apparently there was an adequate amount of available nitrogen present in the soil. Thus the addition of nitrogen resulted in an excess which decidedly delayed maturity and reduced yield. The general effect of nitrogen treatment alone was an increase of top growth without a corresponding increase in root development whereas potassium permanganate seemed to conduce a well-developed fibrous root system. Thus when the two types of materials were used in combination there seemed to be a morphological and physiological balance which resulted in a greater plant development together with earlier maturity and larger yields.

PHOSPHORUS

Data obtained in this and in previous studies indicate a distinct phosphorous deficiency in many Montana soils. All types of vegetable transplants respond favorably in varying degrees to phosphorus fertilization. The general effects are a definite stimulation of root development of a compact, fibrous nature, an increase in top development but to a lesser degree than in the roots, a substantial increase in total dry weight and earlier maturity. The onion responses to phosphate fertilization were most apparent during the transplant stage, but on the phosphate treated plants which were grown very close together in the seed flat, a reversal in performance took place after field planting. This was probably the result of a greater injury to the larger well-developed root system. Where the onions were given more room in the transplant stage, the phosphate treated plants continued to develop ahead of the check plants in the field.

A combination of phosphorus and dextrose was particularly favorable for the development of head lettuce. Combinations of phosphorus

and dextrose, and phosphorus and potassium permanganate were both conducive to the rapid development of onion and cabbage transplants. The desirable effects also carried over into the field.

POTASSIUM PERMANGANATE AND DEXTROSE

Both potassium permanganate and dextrose when used alone as a transplant treatment have the general effect of stimulating root development. In the case of tomatoes, this response has caused a great reduction in the amount of cracking of the tomato fruits which is quite a serious problem in localities where tomato plants are pruned and staked. Although potassium permanganate appeared to have a slightly toxic effect upon the root tips of some of the vegetable transplants there also was a decided increase of fibrous secondary growth which resulted in a very compact and well-developed, efficient root system. In the case of celery transplants, the toxic effect was most pronounced causing an actual stunting of growth, whereas in the other types of transplants a general stimulation of growth resulted. Potassium permanganate is known to be a very effective oxidizing agent; thus when applied to the soil it may greatly increase the availability of nutrient materials, probably phosphorus, as was evidenced by the typical phosphorus response whenever potassium permanganate was applied. Dextrose, even when used alone, was very conducive to plant development. This was particularly true with head lettuce during the transplant stage. An increase in both root and top development was noted. Dextrose also materially improved the quality of the early head lettuce crop. On tomatoes, dextrose has given a decided increased growth response which resulted in delayed maturity together with increased total yields, the heavy yield coming late in the season. A larger ratio of No. 2 to No. 1 tomatoes also accompanied dextrose fertilization. The favorable effects of dextrose on plant growth might possibly be explained on the basis of the effect of direct absorption of material by the plant or by the probable indirect effect of dextrose in stimulating the development of certain beneficial microflora of the soil. This may account for the typical nitrogen response with the exception that dextrose actually increased the effective root area of the transplant whereas nitrogen seemed to inhibit natural root development.

POT TREATMENTS

The records of pot treatments carried out on tomato and pepper transplants indicate that 4-inch pots are decidedly better than the smaller sizes and also that they are superior to paper bands. Nitrogen, when used with the paper pot treatments, seemed to offset the undesirable stunting effect of the paper pots on the vegetable transplants. In all cases, any of the pot treatments can be strongly recommended in favor of flat treatment. This is particularly true where large transplants are desired. In spite of the fact that the greatest fertilizer responses on the transplants were noted in the smaller pot treatments, greater injury was noted at the time of field planting which resulted in smaller yields due to inhibited plant development.

TEMPERATURE EFFECTS

Temperature differences within the range found in most commercial green-houses affect vegetable transplants to the extent of approximately doubling growth rates, for every 10 degrees F rise. Thus marketable vegetable transplants can be developed in a shorter period of time by growing them at higher temperatures. This is particularly true with the warm season plants, such as tomatoes and peppers. For tomatoes, low temperatures are favored for 70-day transplants and for 55-day transplants high temperatures are favored where not too costly and where earliness of the vegetable transplant is essential. Otherwise low temperatures are best. In the case of onions grown at minimum temperatures 43 to 53 degrees F, transplants were superior to those grown at minimum temperatures of 60 to 70 degrees F.

Temperatures also seemed to have a decided effect on the availability and effectiveness of the different fertilizer and chemical treatments. Dextros as a soil treatment seemed to be relatively ineffective at temperatures below 60 degrees F, whereas at 60 to 70 degrees F, it had an appreciable influence on plant growth, possibly due to its effect on soil micro-organisms which may be relatively inactive at the lower temperatures.

In the case of onions grown close together in the seed flat at low temperatures, those produced at a minimum of 43 to 53 degrees F, were superior to those grown at high temperatures. If, on the other hand, the transplants were given more room in the seedling flats, the higher temperatures were preferable since the wider spacing permitted transplanting without excessive root injury. The amount of space given to the vegetable transplant in the seedling stage has a tremendous influence on the amount of injury caused by field planting. Such injury is directly proportional to transplant size and spacing. Thus, if any benefit is to be gained by transplant treatment, the transplant must be grown with adequate space for root development and must be handled so as to reduce injury at the time of field planting to a minimum.

CONCLUSION

Although the present knowledge concerning the effects of various methods of handling vegetable transplants on the performance of the vegetable crop is very meager, all indications point to the fact that vegetable crops can be materially affected by modifying the transplant methods. Furthermore, progress in this regard will be stimulated by the discovery of improved laboratory methods for determining the specific manner in which nutrients of various kinds affect the fundamental physiological processes of the plant in bringing about the observed qualitative and quantitative changes.

Resistance to Corn Earworm Injury in the Charleston, South Carolina Area¹

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THE United States Regional Vegetable Breeding Laboratory at Charleston, South Carolina, included among its 1935 plantings an earworm resistance test of maize varieties and hybrids. The test comprised three separate units,—plot 1 contained several standard varieties for direct comparison with a group of backcross hybrids made from 1934 to 1935, and tested in 1935 (1); plots 2 and 3 were units containing F_1 , F_2 , or backcrossed populations from more recent crosses never before tried in a comparative way. All crosses were made in California¹ with parents which gave some promise of earworm resistance in 3 years of trial. The F_2 and backcross stocks were mostly sugary segregants, both yellow and white when possible, from dent x sugary crosses. The chief purpose in raising plots 2 and 3 was to establish inbred and controlled cross pollinated lines for new sweet corn stocks in the southeastern states, and for this reason earworm resistance was estimated only on the open pollinated ears remaining unbagged. Earworm resistance is shown by the "Resistance Index", obtained by grading the degree of earworm injury on a six point scale: no injury at all = 5, unmarketable condition = 1, more severe injury = 0.

Small amounts of seed were sent from California for these plantings, but this was sufficient for two replications of each stock in 32 foot rows. Germinations in plot 1 gave good stands, but those in plots 2 and 3 were unsatisfactory because of injury inflicted (in the soil) by the seed corn maggot, *Hylemyia cilicrura* Rond. In some stocks of plots 2 and 3 the injury reduced the stand so seriously in one of the two replicates that no open pollinated ears were available for classification of earworm injury, and no bagged ears were procured for further inbreeding. The data of all plots were analyzed statistically by the variance method, but only in plot 1 (see Table I) was the F value significant, that is, the variance between treatments exceeded the variance for strains or varieties.

Tuxpan and Davis Prolific, two southern dent varieties, repeated the excellent showing made in 1935 at California, when they displayed higher resistance than any maize varieties tested. The California test (data unpublished) included four replicates of 12 varieties, and gave a smaller standard error of a mean difference, 0.26, than in the present test of two replicates of 20 varieties, 0.42, see Table I. In both tests, however, the two varieties ranked well ahead of Surcropper Sugar and Honey June, although not significantly so. Four sweet corns in the present test outrank Surcropper Sugar and Honey June; namely, Aunt Mary's Sweet, Purdue 51 (an inbred Golden Bantam selection), and two backcross populations obtained by crossing Honey June with two northern sweet corns, Golden Bantam and Oregon Evergreen, re-

¹All references in this paper to work in California relate to investigations by the writer while on the staff of the California Agricultural Experiment Station, and the contributions of the California Station are hereby acknowledged.

TABLE I—EARWORM RESISTANCE AND GROWTH DATA, VARIETY TEST PLANTED MAY 4, 1936, CHARLESTON, SOUTH CAROLINA

H. J.=Honey June, G. B.=Golden Bantam, O. E.=Oregon Evergreen, T. F.=Trucker's Favorite, G. S.=Golden Sunshine, S. S.=Surcropper Sugar.

	Number Ears Classified	Resistance Index	Average Number Days to Roasting Ears	Average Height (Feet)	Average Ear Dimensions	
					Diameter (Inches)	Length (Inches)
1. Tuxpan	55	2.91	100.0	8.1	1.75	8.25
2. Aunt Mary's Sweet	40	2.89	83.6	5.0	1.46	5.48
3. Davis Prolific	62	2.86	96.6	7.6	1.69	7.89
4. (H. J. x G. B.) H. J.	60	2.81	84.7	7.0	1.60	6.73
5. Purdue 51	40	2.71	80.8	4.2	1.38	6.06
6. (O. E. x H. J.) H. J.	60	2.52	88.8	6.4	1.64	6.19
7. Honey June	42	2.45	89.6	6.9	1.75	6.32
8. Surcropper Sugar	71	2.32	90.3	6.3	1.61	6.17
9. Oregon Evergreen	50	2.24	84.8	5.7	1.65	6.69
10. (O. E. x H. J.) O. E.	40	2.24	86.4	5.8	1.63	6.36
11. Florida 191	59	2.15	88.9	6.1	1.56	7.37
12. (G. S. x H. J.) H. J.	51	2.07	79.4	6.7	1.67	6.51
13. (T. F. x O. E.) O. E.	54	2.06	84.1	6.3	1.60	6.45
14. Bantam Evergreen	46	1.92	78.5	4.8	1.62	6.04
15. Alameda Sweet	45	1.87	74.0	4.1	1.62	6.00
16. (H. J. x G. S.) F ₁	28	1.66	75.0	4.7	1.56	5.61
17. Purdue Bantam	33	1.65	76.9	4.4	1.50	6.17
18. (S. S. x G. S.) F ₂	30	1.30	77.8	5.6	1.54	5.70
19. (O. E. x S. S.) O. E.	23	1.16	91.9	5.2	1.55	5.72
20. (S. S. x G. S.) G. S.	26	0.89	74.9	4.8	1.62	5.55

Data for Resistance Index:

Standard error single determination 0.418

Standard error mean difference 0.418

Significant difference 0.836

F = 3.88 5 per cent significance = 2.18

1 per cent significance = 3.11

spectively, backcrossing in each case to Honey June, and artificially crossing within the population to maintain vigor. These last two backcross-derived populations produced better than Honey June in 1935 at Davis, California (1), but Aunt Mary's Sweet and Purdue 51 had never before been studied for earworm resistance. The resistance indices in this Charleston test show more severe earworm injury than was observed on the same varieties in California.

Aunt Mary's Sweet is a sweet variety, recently introduced by L. R. Bonnewitz, of Van Wert, Ohio, which is reported to be very old, probably obtained from local Indians over a century ago and grown continuously on one homestead near Darby Plains. This variety may therefore be one of the few sweet corns known to have been cultivated by North American Indians before white settlers came West (2). Although Aunt Mary's Sweet ranked second in this test, with a resistance index of 2.89, practically identical with Tuxpan and Davis Prolific, the large size of the standard error, 0.42, throws doubt on any estimates of superiority among the first 13 stocks on the list. The discovery of Purdue 51 as an earworm resistant sweet corn is surprising because

neither Golden Cross Bantam, derived from it, nor Purdue Bantam, the other parent of Golden Cross Bantam, show any promise; in fact, Purdue Bantam is one of the most susceptible varieties yet treated.

There seems to be no doubt concerning the real superiority of Tuxpan and Davis Prolific, however, because both varieties have shown the highest promise previously in Texas, in 1935 in California, and this year at Charleston, South Carolina. A comparison of the resistance indices of the best hybrid stocks of plot 3 with the indices of other stocks in the three plots also indicates a marked prepotency of these two varieties as parents of earworm resistant sweet corns.

The indices in plot 2 of lines of Tuxpan and Davis Prolific inbred one generation, when compared with the open pollinated stocks of plot 1, suggests that inbreeding has somewhat lowered their resistance to earworm attack. In the second inbred generation, there will be 13 lines

TABLE II.—EARWORM RESISTANCE OF THE BEST FOURTEEN HYBRID STOCKS IN PLOTS 2 AND 3 GROWN AT CHARLESTON, SOUTH CAROLINA, 1936

P. W. = White Papago, P. Y. = Yellow Papago, D. P. = Davis Prolific, T. = Tuxpan, S. S. = Surcropper Sugar, H. J. = Honey June, G. S. = Golden Sunshine, O. E. = Oregon Evergreen, C. G. = Country Gentleman, G. B. = Golden Bantam, K. P. = King Philip.

Stock	Number of Ears Classified	Resistance Index	Number Ears Selfed
<i>Plot 2, 33 Stocks Total, Planted May 4</i>			
1. (P. W. x Fla. 191) F ₂	11	2.91	3
2. (Mex. June x P. Y.) F ₂	7	2.86	2
3. Cuban Yellow Flint	34	2.62	13
4. D. P. Inbred	7	2.54	13
5. (Mex. June x P. W.) F ₂	4	2.50	1
6. Tuxpan Inbred	23	2.42	7
7. (Mex. June x P. W.) F ₂	27	2.28	11
8. (S. S. x Snowflake) F ₂	21	2.25	9
9. (Alameda x Mex. June) F ₂	28	2.15	6
10. (H. J. x Mex. June) F ₂	18	2.14	11
11. (G. S. x P. Y.) F ₂	9	2.08	7
12. (H. J. x Purdue 39) F ₂	28	1.92	8
13. (O. E. x Alameda) x K. P. 39	24	1.86	6
14. (O. E. x K. P. 38) F ₂	13	1.85	9
<i>Plot 3, 25 Stocks Total, Planted May 22</i>			
1. (O. E. x T.) x T.	47	3.67	11
2. (T. x O. E.) x T.	31	3.20	12
3. (D. P. x C. G.) x D. P.	17	2.97	11
4. (T. x Unknown Yellow) F ₂	51	2.55	10
5. (T. x C. G.) x T.	45	2.33	9
6. (D. P. x C. G.) x D. P.	42	2.30	10
7. (White Flint x D. P.) F ₂	29	2.03	10
8. (C. G. x D. P.) F ₂	10	2.00	5
9. (G. B. x D. P.) F ₂	2	2.00	1
10. (G. B. x T.) F ₂	21	1.95	7
11. (C. G. x T.) F ₂	14	1.84	4
12. (G. B. x T.) F ₂	15	1.78	7
13. (C. G. x T.) F ₂	31	1.72	10
14. (C. G. x T.) F ₂	48	1.50	16

of Davis Prolific and seven lines of Tuxpan, for observation of a possible segregation of factors for resistance.

The data from the best stocks of plots 2 and 3 show convincingly that Tuxpan, Davis Prolific, Papago, Mexican June, and Oregon Evergreen, are outstanding as parents of earworm resistant sweet corn stocks. Papago in both its yellow and white phenotypes figures as a parent in each of the first four hybrid stocks in plot 2, and Mexican June figures in three of the same four. It is noteworthy also that Oregon Evergreen when combined as the sweet corn parent with Tuxpan, is superior to other sweet varieties, such as Country Gentleman, Golden Bantam, and many others not producing hybrids promising enough for inclusion in the first 14 stocks. King Philip, a promising yellow dent variety, is apparently not very important as a parent, judging from the relatively minor position of its hybrids in plot 2.

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Some Cellular Changes in Celery During Freezing and Frost Hardening¹

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DURING the progress of a study concerned with the factors effecting the degeneration of celery in cold storage in Montreal, a condition of injury appeared upon the plants within 3 weeks of harvest which greatly reduced their marketability. This injury consisted of numerous depressed lesions scattered on either side of the petioles, and confined chiefly below the first node. These lesions differed somewhat in their external appearance on the convex and concave sides of the petioles. Those on the convex side were essentially elongated along the vertical axis of the petiole, the depressed area being restricted mainly to the parenchymatous tissue lying between the collenchymatous ridges.

The epidermis was separated from the parenchyma, and lay ruffled and loose upon this part of the lesion, being in many cases ruptured, while it remained firmly affixed to the strands of collenchyma (Fig. 1).



FIG. 1. Showing the typical appearance of frost lesions on the convex side of the petiole.

On the concave side of the petiole, however, the lesions tended more to have a circular outline, with the epidermis loosened but unruptured on the surface (Fig. 2). In all cases, they developed a nut-brown color, and an unsightly appearance, sufficient to render the plants unmarketable.

The possible causes of this condition were investigated. Since it was suggested that pathogenic infection might be a factor, numerous isolations from the lesions were made, but in no case was any organism found, which was capable of inducing the same condition upon reinoculation to fresh material. Entire petioles bearing the lesions were cultured at room temperature; no enlargement of the lesions was observed.

The accidental discovery that when celery is submitted to a slowly declining temperature, freezing results in the formation of ice masses,

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²The author wishes to express his appreciation to Professors T. G. Bunting and H. R. Murray of the Department of Horticulture, Macdonald College, Quebec, who supplied the materials and facilities that made this work possible, and to Dr. G. W. Scarth, Macdonald Professor of Botany, McGill University, for his advice and assistance in the work.

on the petioles, of similar location and outline to those of the lesions, suggested that frost might be a causal factor.

EXPERIMENT

Accordingly, plants bearing these ice masses were thawed out at room temperature and returned to cold storage at 32° F. Within 4 weeks lesions developed on the locations previously occupied by the ice masses, — identified by markings.

Microscopic examination of sections of the affected tissue, cut from fresh material, showed the cells in the center to be completely collapsed along their short dimension, the two long sides lying compactly side by side, while towards the periphery of the lesion the intensity of the collapse diminished, so that cells could be found which showed partial collapse, the short walls having a crinkled appearance. In such cells

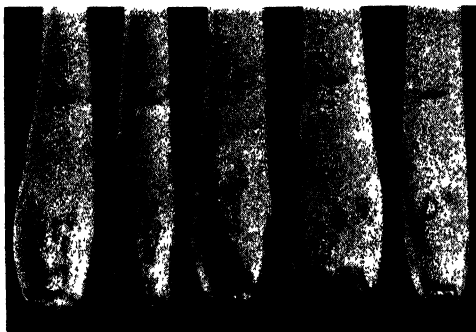


FIG. 2. Showing the typical appearance of frost lesions on the concave side of the petiole.

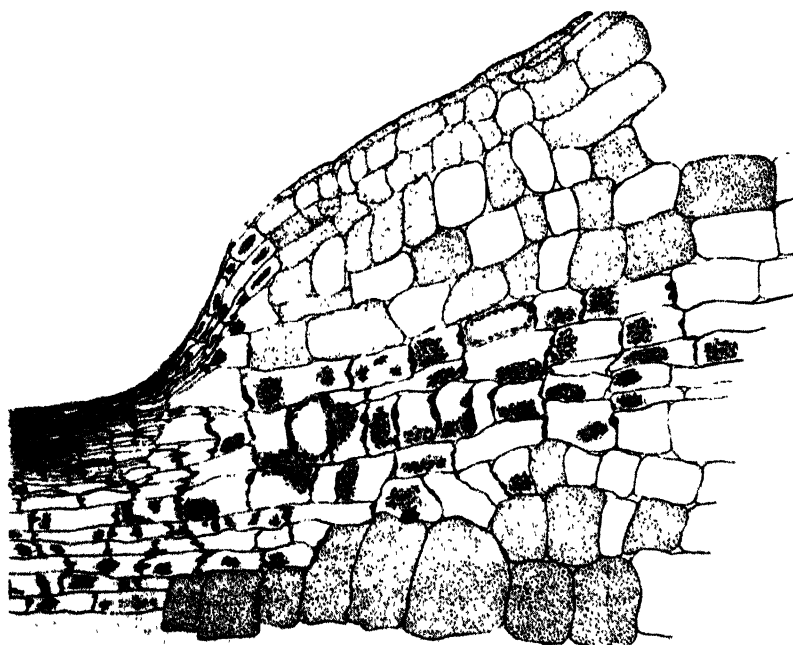


FIG. 3. Camera lucida drawing of a longitudinal section through the periphery of a frost lesion that developed in cold storage. (Normal cells shaded.)

moribund protoplasm was found lying in fragments within the injured cells. Some of these cells lay out among sound, living cells at some distance from the seat of the lesion (Fig. 3).

Sections cut from tissue immediately below an ice mass, following thawing, showed the same condition of crinkled walls and fragmented protoplasm as seen in sections from the collapsed lesions (Fig. 4).

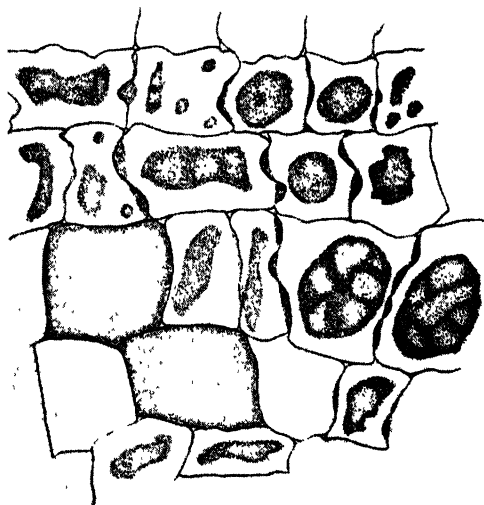


FIG. 4. Camera lucida drawing of a longitudinal section through tissue lying beneath an induced frost lesion. Note moribund protoplasts and crinkled cell walls, as seen in Fig. 3.

These findings are quite similar to those reported by Iljin (3) in red cabbage as a result of slow freezing. Iljin's concept of the injury is that on freezing, the water is removed from the cells to the intercellular spaces and crystallized there, the amount removed being a function of the suction tension of the cells concerned and the depression of the temperature. This dehydrates the cells, and the greater the temperature drop, the greater the degree of dehydration. Eventually, if the temperature drop is excessive, the entire cell,—vacuole, protoplast and cell wall,—becomes reduced to an absolute minimum

of water content. At this stage, the cell is completely shrivelled, the cell walls meeting across the cellular lumen and squeezing the protoplasm into small fragments devoid of vacuole. Upon thawing, however, the cell wall, because of its high imbibitional pressure, absorbs water at once and expands. The protoplasm absorbs water also, but unless the water can enter the protoplasm as rapidly as it enters the cell wall, the wall will quickly separate from the protoplasm, with which it has been in intimate contact, and result in a rupture of the plasma membrane. The effect is similar to too rapid plasmolysis in a highly hypertonic solution.

Iljin found that if he thawed the tissue slowly, or in a hypertonic solution of CaCl_2 or AlCl_3 , he could freeze red cabbage tissue to below -11 degree C and restore it to normal condition, while death ensued under normal conditions of thawing, even for hardened plants, when they were frozen at -5 degree C.

This explanation of the injury by Iljin may well be considered to account for the condition described here, as the cellular observations correspond closely with Iljin's illustrations.

The question arose as to why this specific type of injury should

have been so prevalent upon Quebec grown celery in 1934 as compared with previous years. Reference to daily temperature records for September 1934, for the location where the celery was grown, revealed the fact that the minima temperatures in no case fell below 45 degrees F and in most cases were above 50 degrees F, while the maxima approached 85 degrees F after the 25th of the month. On October 1st, however, the minimum temperature dropped to 27 degrees F, thus subjecting the plants to a slight freeze. As the common practice among growers in that locality is to leave celery in the field until the first slight frost, this particular frost was not regarded at the time as serious. However, in view of the remarkably high temperatures during the preceding 3 weeks, followed by the disastrous ultimate effects of the slight freeze, it was suggested that there might be a certain amount of hardening occurring during the last few weeks before the first frost in normal years, when a slight frost had little or no damaging effect upon the crop.

Levit and Scarth (4) find that with certain herbaceous plants, those capable of resisting mild freezing following a hardening treatment, show an increase in osmotic pressure to a certain definite maximum, but that this maximum is insufficient to account entirely for the observed resistance. They further find (5) that these same herbaceous plants show a marked increase in plasma membrane permeability to water as a result of the hardening treatment, and they suggest that this increase might be a factor in decreasing the injury due to freezing.

The fact that the foliage of the affected plants showed practically no injury at harvest whereas the petioles developed serious injury, suggested that there was a differential resistance between various parts of the same plant. Gonzales (1) presents evidence that the freezing point of the leaf lamina in celery is higher than that of the petiole base. He determined the freezing points by the thermocouple method. Observed differences were extremely small, the greatest difference between leaf lamina and petiole being found in the variety Emperor and amounting only to .7 degree F, in plants removed directly from normal growing temperatures. The effect of cold treatment upon the freezing point showed an average difference of .3 degree F between the hardened and non-hardened plants.

Accordingly, an experiment was conducted to determine the following facts: (a) Whether a gradient of osmotic pressure occurred along the petiole of a normal growing celery leaf from base to leaf lamina, and what the effect of a cold treatment would be upon such a gradient; (b) what effect a cold treatment would have upon the plasma membrane permeability to water; and (c) whether a cold treatment would render the plants capable of resisting a slight freezing without injury.

MATERIALS AND METHODS

Young celery plants, Golden Plume variety, grown in pots in the greenhouse at a temperature of 60 to 70 degrees F, and standing about 10 to 12 inches above soil level, were employed. A single outer petiole was removed from each of three plants, and longitudinal sections cut

from it of 50 microns in thickness. These were stained for 20 minutes in Neutral Red solution (5 ppm in .05M CaCl_2 aqueous solution) and then transferred to a range of CaCl_2 solutions varying from .20 to .30M, and allowed to remain 15 minutes, when they were removed to a drop of the same solution on a slide, covered and examined microscopically. Only cylindrical cells were employed. Measurements were made of the normal length of the cell at incipient plasmolysis (L), the length of the plasmolysed protoplast (h) and the width of the cell (d), from which data the degree of plasmolysis (G) could be calculated from the formula proposed by Höffler (2) :

$$G = \frac{h - 1/3 d}{L}$$

The osmotic pressure of the cell, at incipient plasmolysis, may then be calculated from the relation :

$$\text{O.P.} = G (i.R. T. C.) \text{ atmospheres.}$$

where i is the isotonic coefficient, R the gas constant, T the temperature in degrees absolute and C the molar concentration of the plasmolytic.

Permeability of the plasma membrane to water was determined on a relative basis, the time required for the protoplast to deplasmolyse across a definite gradient of concentration being taken.

The locations of the sections studied are indicated in Table I. These three plants together with others were placed in a cold chamber held at 3 degrees C, supplied with constant light (1,000 watts) and retained there for 10 days. They were then removed and the above observations again made from petioles taken from the same three plants.

The other hardened plants were then returned to the cold chamber together with unhardened controls and the temperature dropped slowly to -2.0 degree C, *i.e.* within 24 hours.

RESULTS

Table I shows the osmotic concentrations, at incipient plasmolysis,

TABLE I—SHOWING THE GRADIENT OF OSMOTIC PRESSURE OF PARENCHYMA CELLS UP A CELERY LEAF PETIOLE BEFORE AND AFTER COLD TREATMENT AT 3 DEGREES C. (READINGS = MEANS OF 30)

Part of Petiole	Osmotic Pressure Before Hardening (Atmospheres)	Osmotic Pressure After Hardening (Atmospheres)	Difference
Base within first 2 cms of base	10.3	14.3	4.0
First node within 2 cms above first node	12.2	16.4	4.2
Second node within 2 cms above sec- ond node	13.0	17.7	4.7
Leaf tip the midrib of the tip leaf lamina	14.3	18.9	4.6

found at the various points on the petiole studied, both before and after hardening. These data are the means of ten readings from each of three plants. The data were submitted to statistical treatment to deter-

mine the amount of error, and the observed changes due to hardening were found to be significant to odds of 99:1.

TABLE II—SHOWING THE EFFECT OF COLD TREATMENT UPON THE PLASMA MEMBRANE PERMEABILITY TO WATER IN CELERY PARENCHYMA TISSUE.
(READING = MEANS OF 30)

	Deplasmolysis Range, M CaCl.	Deplasmolysis Time (Minutes)
Before hardening	.50 .18	6.2
After hardening	.58 .26	1.0
	Difference	—
		5.2

Table II shows the changes found in permeability of the plasma membrane to water as a result of the cold treatment. These data also were found to be significant to odds of 99:1.

The plants submitted to -2.0 degree C were examined after 6 hours. The hardened plants showed no ice masses at all, while slight ice masses could be seen on the unhardened controls. After 12 hours, however, all the plants showed ice masses accrued at various places on the petioles, although the leaves of the hardened plants showed no visible freezing. Following the freezing treatment all the plants were removed to the greenhouse and held at 60 to 70 degrees F.

Final observations on the plants, 5 days after their removal to the greenhouse, showed that the hardened plants were apparently quite sound. The unhardened plants, however, showed the typical injury as seen in the field, i.e. drooping leaves, ruptured epidermis and chlorotic foliage.

DISCUSSION

The fact that the injury on celery petioles described in this paper may arise from slight freezing under certain conditions, and that such injury reduces the marketability of affected plants, points to the practical importance of considering the time of harvest in relation to weather conditions. It would appear from the data presented that when the minimum temperatures are comparatively low, i.e. between 32 degrees and 45 degrees F, for the last 3 weeks preceding harvest, the grower may risk harvesting his crop after the first slight frost; but in cases where the temperatures just preceding harvest are above 50 degrees F it would seem wise to harvest before frost appears, if possible. In many cases, however, the grower has no means of predicting the time and intensity of the first frost. Under such circumstances, then, should the crop undergo a freeze in the unhardened condition, it would pay the grower to market it as soon after harvest as economically possible, and not risk long storage charges on a product that might succumb to severe shrinkage.

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The Development of Powdery Mildew Resistant Cantaloupe No. 45

By I. C. JAGGER, *U. S. Department of Agriculture, La Jolla, Calif.* and
G. W. SCOTT, *University of California, Davis, Calif.*

ABSTRACT

The complete paper will be published as a U. S. D. A. Department Circular.

THE paper gives in detail the steps in the development, by crossing, backcrossing and selecting, of a powdery mildew resistant strain of cantaloupes, known as Powdery Mildew Resistant Cantaloupe No. 45. This strain seems to have solved the mildew problem in the Imperial Valley of California, by far the leading cantaloupe district of the country, where the crop had been seriously ravaged for several seasons.

Cucurbita Hybrids¹

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THE genus *Cucurbita* comprises that composite group of annual, edible, commonly cultivated gourds known as pumpkins and squashes² together with several other less important species. Botanically we distinguish three common species of these vegetables, namely:

A. *Cucurbita maxima* Duch., of which "Hubbard squash", "Boston Marrow", "Delicious" and "Banana" are fairly representative;

B. *C. Pepo* L., in which the ordinary "Field pumpkin", the "Patty Pan" or "Scallop", the "Crookneck squash", and certain fall squashes such as "Fordhook" and "Delicata" as well as the well-known "Table Queen" are included. "Connecticut Field" of this group, often vies with "King of the Mammoths" and "Giant Chili", both *maximas*, for the honor of being the largest "pumpkin" at various state and county fairs; and

C. *C. moschata* Duch., which embraces the "Cushaws" or "Winter Crooknecks", "Large Cheese", "Tennessee Sweet Potato", "Japanese Pie" and other horticultural forms.

For precision's sake, we will use these botanical epithets and confine our discussion to (a) *maximas*: mostly rough hairy vines with rounded, slightly lobed leaves having naked basal veins, with rounded lobes in the flowers, and with soft spongy stalks on the fruits; (b) *Pepos*: both running and bushy, harsh prickly plants with generally more acutely lobed leaves, likewise having partially naked basal veins but with more pointed corolla lobes, and with hard, ridged and angled fruit stalks; and (c) *moschatas*: mostly soft hairy vines (soft hairy at the tips, at least) with often acutely angled leaves having the basal veins nearly or quite covered by the decurrent blade, with pointed corolla lobes, and with hard and generally either ridged and flaring, or more or less amorphous, fruits stalks, appearing corky (to the eye, not the hand). There are other minor characteristics of each; but the chromosome numbers are the same for all, 40 diploid, with apparently some variation in various strains or perhaps in some horticultural varieties as a whole.

The latter part of this statement needs elaboration since both Castetter (3) and Whitaker (4) have published a figure of 48 for the chromosome number of the *moschatas*. There need be no doubt that they found 48 in their materials. However, Whitaker in a later cytological examination of *moschata* material (unpublished) found but 40, and Castetter (3) noted that his counts differed from those of Lundegardh (5) and Kozhukhor (6). Dr. Ruttle (7) at the Geneva Station, counted chromo-

¹New York State Agricultural Experiment Station Journal Paper No. 191.

²Squash and pumpkin are culinary terms, precisely speaking. Squash are table vegetables and pumpkins are used in pies and as cattle feed. Attempts have been made both here (1) and abroad (2) to limit the application of these terms to botanical entities but, unfortunately, the terms were applied, in the two instances cited, in a diametrically opposite manner. The public still applies the terms according to local custom.

somes in some excellently prepared *moschata* material which clearly showed. The genetic evidence of hybrids produced, suggests equal numbers of chromosomes in the plants successfully hybridized and it might be inferred that some of the unsuccessful crosses were perhaps due in part to a varying chromosome status in the plants involved. The subject merits further study.

Hybridization or at least attempts at hybridization of these species began a little over 80 years ago with the work of Charles Naudin (8) at the Jardin de Plantes in Paris. His account is delightful reading and suggests more facts to us now than he was able to deduce at that time. He noted, for instance, the almost incredible activity of bees in the flowers at daybreak, the stripping of pollen from the stamens within a few moments, and the equally rapid and thorough pollination of the female flowers; but he thought mid-afternoon of a very hot day the proper time to cross-pollinate. Interspecific crosses made before 6 o'clock in the morning at the Geneva Station have been approximately 90 per cent more successful than those made later using the same varieties. From 68 crosses, Naudin secured but seven fruits and no fertile seed strong enough to produce F_1 plants. In addition to the three more important species of *Cucurbita* he also used in some crosses the wild gourd or calabazilla of our southwestern states, *C. foetidissima* H. B. K. (*C. perennis* Gray), and the Malabar gourd, *C. ficifolia* Bouche (*C. melanosperma* A Br.).

The accompanying table shows the successful hybrids that have been produced since Naudin's time. No attempt has been made to include here accounts of the numerous unsuccessful attempts.

To Dr. Bailey (9) of Cornell goes the credit of the first successful interspecific hybrid in the genus *Cucurbita*. During a decade or more, some 40 to 50 years ago he hybridized a large number of Cucurbits and secured fertile seed from three fruits,—hybrids of *C. pepo* and *C. moschata*. Eighty-eight F_1 plants were grown from crosses of "Connecticut Field" by "Japanese Crookneck" and a few F_2 plants were grown.

Oscar Drude (10) of the Botanical Institute of Wurzburg, Germany, over a period of about 25 years (1892 to 1917) once succeeded in hybridizing *C. Pepo* with the Malabar Gourd and was able to back-cross the hybrid with *C. Pepo*.

Dr. Byron Halsted (11) of the New Jersey Experiment Station reported in 1909 a successful and fertile hybrid between a pistillate *C. moschata* and a staminate *C. maxima*. F_1 plants were grown but the experiment seems to have been dropped at that point.

A. C. and A. L. Hagedoorn (16) in 1912 succeeded in crossing a "yellow bush squash" apparently of the same type as Golden Custard, with "Turkenbund", a turban squash. They raised F_1 and F_2 plants.

The most extensive and successful program of hybridizing was that of Castetter (3) at the Iowa Station. The chart shows the large number of fertile hybrids he secured. For some unknown reason he, as well as all others who had attempted it, was unable to secure hybrids of *C. moschata* with *C. Pepo* pollen although the reciprocal cross was readily obtained.

In 1933 the writer determined to try this cross again as he felt that

it must be possible in view of the hybrids already secured. About a hundred pollinations and reciprocal crosses were made with bagged flowers, and at varying periods throughout the day. Of the first set of crosses attempted, only those pollinated before 7 a. m. retained fruit for a period of a week. Repetitions of the experiment through the summer confirmed the value of early morning crossing. The bags used were of parchment-like paper and were placed over the flower buds on the evening before pollination was attempted. The bags were secured by a loop in the string attached to an ordinary cardboard marking tag. There seems to be some factor involved in handling the flowers, as well as in the time of pollination and method of bagging, since a large number of pollinations made during this past summer by an assistant who apparently followed the same technique with the same varieties were unsuccessful.

A prime reason for attempting these hybridization experiments was a desire to learn the extent of variation in inheritance of characters used for delimiting the species taxonomically. However, a most interesting by-product of the investigation appeared in 1934 when the first crop of F_1 plants was grown. The field used was riddled with mosaic and almost every *Pepo* grown in the immediate area sooner or later succumbed to the disease but not one of the hybrid plants with *moschata* as a pistillate parent showed the least sign of the virus. The possibility of producing high quality "summer squashes" with resistance to mosaic loomed as a problem overshadowing the original intent of the investigation. A few F_2 plants from selfed F_1 flowers were grown in 1935 but the writer was on leave for most of the growing season and no records beyond several photographs of fruits were kept. The past summer's drought prevented the development of mature fruit on the F_2 plants before frost. However, a group of new and repeated crosses were secured from some plants grown in another plot where the water level remained fairly high despite the lack of rain, and these will be grown next season.

After this paper was started, a colleague, W. D. Enzie, reported having recently seen hybrid *Cucurbitas* at the Oregon Experiment Station. A letter of inquiry elicited a prompt and courteous reply from Dr. B. F. Dana, Plant Pathologist at Oregon State College, who stated that he had started his hybridization experiments "for the purpose of developing varieties resistant to the curly top virus." "The original crosses were made in the greenhouse and a limited representation of the F_1 generation has been grown and successfully selfed likewise in the greenhouse." Dr. Dana's hybrids are also shown on the chart.

In all cases, so far as known, the *moschata-maxima* combinations have shown staminate sterility but are easily back-crossed with the parents; the *Pepo-maxima* crosses produce relatively few fertile seeds; and the *moschata-Pepo* hybrids are very prolific.

It may be added that the writer interprets the foregoing facts as suggesting an early separation of the *maximas* from the more primitive forms, a later separation of the *Pepos*; and a close alliance of some, at least, of the *moschatas*, with the original type or types of the annual *Cucurbitas*. There are other reasons for this systematic disposition but they will be dealt with, more properly, elsewhere.

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A Male-sterile Onion

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THE practical utilization of "hybrid vigor" to secure increased yields and other beneficial results had its inception and its present extensive practical application in the growing of field and sweet corn. This is probably because of the ease with which cross pollination can be accomplished. The use of hybrids in the production of many other crops has not been practiced chiefly because of difficulties encountered in securing sufficient quantities of crossed seed. When these obstacles are overcome no doubt the principles worked out in corn can be applied more extensively. In this paper there is presented a case where this technique, perhaps, may be profitably employed in the production of hybrid onion seed.

In a population of Italian Red onion plants grown at Davis, California, in 1925, one was found that proved to be completely self sterile. All the plants were self pollinated by enclosing each umbel in a paper bag, and on this particular plant a quantity of bulbils but no seed was produced. Because of its ability to produce bulbils it has been possible to perpetuate this selection asexually. Since the bulbils can not be kept in storage for long they are usually planted in California in the nursery 2 to 3 weeks after being harvested and are overwintered as growing plants. The bulbs mature in late June or July and because of their poor keeping quality the mother bulbs are usually planted to the field in September. The following spring seed stalks are formed and flowers produced in abundance. When these are cross pollinated a good set of seed is obtained, but when crossing is prevented bulbils only are secured. This indicates that self sterility is not due to the failure of the female gamete to function.

The causes of sterility in this selection were investigated by Monosmith (1) who found meiosis in the pollen mother cells to be regular and the number of chromosomes to be 16, which is characteristic for this species. She states that the first indication of abnormality is the occurrence of hypertrophy in a few of the centrally located tapetal cells. These degenerate abnormally and following this many or all of the microspores in a locule die. At time of dehiscence the contents of a pollen sac are cemented together and remain within the anther. The mode of inheritance of this type of male sterility has not yet been determined.

This male-sterile selection is characteristic of the Italian Red variety in that it has a delayed bolting habit, develops an elongated, torpedo-shaped large bulb which is mild in flavor and does not keep well in storage. Because of its male-sterile character, mother bulbs of this selection (pedigree 13-35) may be interplanted in the field with male-fertile varieties without danger of contaminating the latter. Seed obtained from the male-sterile plants is all hybrid and corresponds to that secured from a top cross in corn. In an attempt to combine the vigor, delayed bolting habit and other desirable characters of the male-

sterile onion with those of certain inbred lines and commercial varieties a number of controlled crosses have been made, with the object of securing F_1 hybrids superior to either parent and to existing commercial varieties. Of the material tested the variety Lord Howe Island, an inbred line of California Early Red U C No. 1, and an inbred line of Italian Red have shown promise as male parents. The Lord Howe Island variety secured from Australia has a characteristic upright habit of growth. It bolts readily and matures in season with Crystal Wax and Yellow Bermuda. The bulb is deep red, oblate, and does not keep well in storage.

California Early Red U C No. 1 (pedigree 21-22-1) was developed at the California Agricultural Experiment Station and is now being grown commercially in California. This strain has been inbred for two generations and is very uniform for the important commercial characters. It does not bolt readily and matures 3 to 4 weeks later than Lord Howe Island. The bulb is mild, red, and a high flat. It is not a good storage onion, but does keep much better than the commercial variety from which it was selected.

An Italian Red onion, pedigree 13-52-9-6- S_1 , inbred for four generations, showed promise as a pollen parent. Although much reduced in vigor from inbreeding, it was very uniform for all characters.

In 1935 first-generation hybrids between the male-sterile 13-53 and Lord Howe Island were grown in different localities in Central California (Table I) and were compared with the male parent in size of bulb and amount of bolting. Plants of the male-sterile parent were not available for comparison. The percentage of plants of Lord Howe Island which produced seed stalks ranged from 54.3 at Vernalis to 87.6 at Milpitas. None of the F_1 plants bolted at Sacramento or Vernalis, only a small percentage at Davis and Liberty Island, but a higher percentage at Milpitas where climatic conditions favored bolting. The average weight per bulb is for non-bolters only and in all

TABLE I—PERFORMANCE OF THE ONION VARIETY LORD HOWE ISLAND, AND THE F_1 (MALE-STERILE ITALIAN RED 13-53 X LORD HOWE ISLAND) CALIFORNIA, 1935

Location	Variety or Pedigree	Population	Per Cent Bolters	Average Weight per Bulb (Pounds)
Davis	Lord Howe Island	81	86.4	0.11
	13-53* x Lord Howe Island, F_1	108	3.7	.42
Milpitas	Lord Howe Island	81	87.6	.23
	13-53 x Lord Howe Island, F_1	81	18.5	.85
Liberty Island	Lord Howe Island	236	69.9	.25
	13-53 x Lord Howe Island, F_1	143	1.0	.43
Vernalis	Lord Howe Island	291	54.3	.26
	13-53 x Lord Howe Island, F_1	74	0.0	.44
Sacramento	Lord Howe Island	240	65.0	.38
	13-53 x Lord Howe Island, F_1	78	0.0	0.88

*13-53 = Male-sterile Italian Red onion.

locations the F_1 bulbs were heavier than those of the male parent. In 1936 this same cross was grown in comparison with both parents at Davis, California (Table II). None of the male-sterile plants bolted and only 3.7 per cent of the F_1 , but 59.7 per cent of the Lord Howe Island plants bolted. These data indicate that the non-bolting character in this cross is dominant. The F_1 bulbs were heavier than those of either parent and nearly globe shape, being intermediate between the two, but they were not as uniform in size, shape, and color as those hybrids in which bulbs from inbred lines had been used as the male parent.

TABLE II—PERFORMANCE OF FIRST GENERATION BULBS AND THEIR PARENTS. CALIFORNIA, 1936

Location	Variety or Pedigree	Population	Per Cent	Date Mature	Average Weight Bulb (Pounds)
Milpitas	13-53*	5	0.0	July 1	1.14
	California Early Red U. C. No. 1	236	59.7	June 22	.50
	13-53 x California Early Red U. C. No. 1, F_1	80	20.0	July 1	.97
Shafter	California Early Red U. C. No. 1	243	2.5	June 9	.35
	13-53 x California Early Red U. C. No. 1, F_1	81	1.2	June 11	.46
	13-53	28	0.0	June 25	.61
Davis	California Early Red U. C. No. 1	294	18.3	June 13	.50
	13-53 x California Early Red U. C. No. 1, F_1	126	2.1	June 13	.70
	Lord Howe Island	231	59.7	May 19	.37
	13-53 x Lord Howe Island, F_1	27	3.7	June 7	.86
	13-53 x Italian Red 13-52-9-6-S, F_1	12	0.0	June 25	1.22

*13-53 = Male-sterile Italian Red onion.

Another hybrid population and its two parents California Early Red U C No. 1 and 13-53 were grown at Davis and Milpitas in 1936. There was no bolting at either place in the 13-53 population. At all locations the percentage of bolters was higher in California Early Red than in the F_1 , showing that in this cross too the non-bolting character was dominant.

Other conditions being equal, temperature plays an important part in the expression of the bolting habit. This is clearly brought out in the bolting data for California Early Red. The plot at Milpitas, adjacent to San Francisco Bay, was subjected to the lowest average temperature. Here 59.7 per cent of the plants bolted. At Shafter, California, located in the upper San Joaquin Valley, where the highest average temperature prevailed, only 2.5 per cent of the plants bolted, while at Davis, located in the lower Sacramento Valley, where the average temperature is intermediate as regards the other two locations, the percentage of bolters was also intermediate.

The hybrids between the male-sterile Italian Red and California Early Red U C No. 1, were fairly uniform in size, shape, color, and time of maturity, showing the desirability of having inbred pollen parents. In all locations the F_1 bulbs were heavier than those of the pollen parent.

Another hybrid that showed promise was between the Italian Red male-sterile 13-53 and Italian Red, pedigree 13-52-9-6- S_1 . Only a few hybrid plants were grown but these were superior to the commercial variety in most all characters of commercial importance.

It is probable that male sterility can be incorporated in the chromosome complex of other varieties making its use more general. The variety, however, must possess in addition to male sterility the ability to propagate itself vegetatively. But the extent to which male-sterile plants of the onion can be used to produce hybrid seed commercially still remains to be determined.

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Plot and Plant Variation in Virginia Peanuts

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INTRODUCTION

AMPLE evidence in the literature shows that experimental error due to plot variation on land of reasonably good uniformity can be reduced by replication, to a degree conforming closely to the theoretical reduction. We know, however, of no reports of variation among peanut plots of various sizes that would serve as an aid in laying out a field study with the greatest economy of land and work consistent with a high standard of accuracy. These studies were made in efforts to determine: (a) the optimum plot size for testing selections and for conducting studies of special cultural practices and environmental effects; (b) the prevailing degree of variation among plants in a single small plot as a guide in making plant selections and taking composite plant samples.

This paper is presented not as an exposition of new technique or statistical method, but only to indicate the degree of variability likely to be encountered in the peanut, under favorable Atlantic Coastal Plain conditions.

METHODS

Plot Variation:—Uniformly planted and handled portions of fields of the Virginia Experiment Station stock of the Jumbo Runner variety were marked off into 20-foot blocks extending across the rows after the plants had been loosened from the soil with a "digger" and were ready for pulling. The green weight of plants from each 20-foot increment of row was recorded, and the plants were stacked in such a manner that each lot of plants could be identified and picked separately after curing. The weight of picked peanuts was recorded for each row increment, and all data were tabulated to conform to the positions of the 20-foot single row plots in the field.

In analyzing the yield data, different plot sizes were developed by combining the ultimate 20-foot plot yields, and for these as well as for the ultimate plots, variance was determined by Fisher's method.

Plant Variation in Uniform Plantings:—In these studies, all plants in a chosen area were harvested, weighed individually, labeled, stacked systematically, and after curing were picked individually and the weight of peanuts recorded. The statistical values presented here were calculated by the conventional machine methods.

In all these studies the rows were 2½ feet apart, and unless otherwise stated, the plants were approximately 1 foot apart in the row.

RESULTS

Plot Variation:—In many instances data were obtained and calculations made on green and dry weights of plants as well as on weight

of picked nuts. Since yield of peanuts is generally of more interest than total-plant weights only the data on peanut yields will be presented here. Table I shows, on the basis of 3 years' observations, that an individual plot size of about 15 x 20 feet (six 20-foot rows) is large enough for reasonably reliable experimental results. This may be expected to hold good under ordinary conditions and when no physical or cultural difficulties are encountered in the handling of small plots.

TABLE I.—VARIATION IN YIELD OF PEANUT PLOTS OF DIFFERENT SIZES
(VARIANCE EXPRESSED AS COEFFICIENT OF VARIABILITY OF WEIGHTS OF
PICKED PEANUTS PER PLOT. HOLLAND, VA.)

Year	Number and Length of Rows in Plot	Variance			
		Total (Per Cent)	Between Rows or Tiers (Per Cent)	Between Blocks (Per Cent)	Inter- action (Per Cent)
1930	1— 20 ft.	39.3	7.3	29.1	27.0
	2— 20 ft.	31.7	6.3	29.1	13.1
	6— 20 ft.	30.2	4.8	29.1	9.1
	6— 40 ft.	29.6	4.8	29.1	7.4
	6—100 ft.	17.4	4.8	30.2	6.5
1931	1— 20 ft.	34.3	12.3	16.5	28.0
	2— 20 ft.	28.6	9.5	16.5	23.2
	6— 20 ft.	24.1	10.0	16.5	22.5
	6— 40 ft.	25.9	10.0	17.5	20.4
	6—100 ft.	24.7	11.7	13.1	17.9
1932	1— 20 ft.	19.5	7.5	7.6	17.1
	2— 20 ft.	14.7	6.9	7.6	11.3
	6— 20 ft.	12.3	6.1	7.6	8.9
	6— 40 ft.	11.1	6.1	6.9	7.9
	6— 100 ft.	9.3	6.1	5.2	7.5

These results were calculated on a closed system on areas of approximately an acre. In 1930 and 1932, four to six replications of 15 x 20 foot plots in latin squares or modified latin squares, would have resulted in residual errors of means of "treatments" in the neighborhood of 4 to 5 per cent, a very satisfactory value. In 1931, conditions were so adverse that no reasonable plot size or number of replications would have produced that degree of accuracy.

Single Plant Variation:—In an effort to account for the high total variance and interaction of single row 20-foot plots, the weight of picked nuts was determined for each plant in each of ten 20-foot intervals of 13 rows in the field observed in 1932, with the exception of those of a few plots that became mixed or damaged in the stacks. This area was planted to a good commercial stock.

The coefficient of variability of plot yields of 112 such plots was 23.3 per cent, while the coefficient of variability of stand was 15.7 per cent. Contrary to expectations based on earlier publications, the plot yield was not correlated with stand. Despite the fact that stands varied from 16 to 27 plants per 20 feet in most of the plots, (five plots contained 9, 14, 15, 28 and 29 plants, respectively) and yields varied from .68 to 2.20 pounds, the coefficient of correlation between stand and yield was $-.097$. The 5 per cent point in this case is $-.195$.

The coefficients of variability of individual plant yields within a 20-foot row were very high, ranging generally from 40 to 80 per cent. There was a small but significant correlation between stand and variability, ($r = +.284$; 1 per cent point = $+.254$).

These two results emphasize the high degree of competition among peanut plants under the usual conditions of culture. Closer stands, within the limits noted here, resulted in no greater yield per plot but only in a depression of the mean yield per plant. Furthermore, it appears that competition was quite unequal among the plants, certain plants apparently gaining an advantage over their neighbors and depressing their yields, as evidenced by the higher coefficients of variability in the closer stands. The thinner stands (less than 20 plants per 20 feet) contained varying numbers of blank hills which might be expected to result in a higher coefficient of variability than in plots of unbroken stand. Under these conditions, however, it appears that crowding produces more variability than a few missing hills.

These observations of individual plant behavior are valuable, indicating the probable superiority of wider spacing (in this case 18 to 20 inches) in studies involving records or samples of single plants or very small groups of plants, as a means of reducing plant variation; but unfortunately they show nothing as to the cause of yield differences in small increments of rows.

Additional single plant yield data were obtained in 1933 and 1934 on quadruplicate 100-foot single row plots of seven pure line selections and of the Virginia Experiment Station stock of Jumbo to deter-

TABLE II—VARIATION IN YIELD PER PLANT WITHIN 100-FOOT SINGLE ROW PLOTS OF JUMBO TYPE PEANUTS (QUADRUPPLICATE PLOTS)

Strain Number or Designation	Habit	Range in Coefficient of Variability Within Quadruplicate Plots		Coefficient of Variability for Total Plants in Quadruplicate Plots (300 to 400 Plants)
		Low	High	
1933				
110742	Runner	48.2	51.3	52.1
110747	do	40.0	43.9	43.2
110751	do	38.0	45.1	40.8
110872	do	42.2	61.7	55.6
Virginia Station...	do	36.7	58.6	52.2
5-24-3	do	38.9	49.4	44.1
110739	Bunch	35.3	51.6	43.8
110740	do	43.3	51.4	46.7
1934				
110742	Runner	38.7	50.8	46.5
110747	do	27.9	50.5	39.4
110751	do	34.3	42.8	38.3
110872	do	35.4	39.9	37.2
Virginia Station...	do	40.8	50.9	48.1
5-24-3	do	36.2	44.5	40.4
110739	Bunch	38.4	44.5	41.5
110740	do	35.1	40.6	38.0

mine the magnitude and range of variation within and among plots and strains. The results, briefly summarized in Table II, show a higher degree of variation in 1933 than in 1934, and that certain of these pure lines are distinctly more variable than others. Analysis of variance of the original tabulation shows significant differences in variation due only to variety and to year. Neither the replications nor any interaction showed a significant variance when referred to the triple interaction as error. Although there was a marked difference in variability (coefficient of variability) between the 2 years, there was no significant difference in yield per plot between years.

Within a 100-foot single row plot under these conditions, a coefficient of variability of individual plant yield of 35 to 55 per cent may well be expected, but it may be somewhat lower or higher.

CONCLUSIONS

Five years' observations of plot and plant variation with the Jumbo Runner type of peanut under conditions characteristic of good commercial practice, appear to justify the following conclusions and suggestions:

1. A satisfactory and practicable size of plot is 300 square feet, consisting of a single 100-foot row (see low variance due to row in Table I), but preferably five or six 20-foot rows, $2\frac{1}{2}$ to 3 feet apart.

2. Competition is pronounced in Jumbo Runner peanuts planted a foot apart in the row. Variations in spacing from an average of 9 inches to 15 inches under good conditions of culture and fertility have not produced significant differences in yield per plot.

3. The high degree of competition accompanying close planting tends to produce a higher variation among the plants in a single plot when closely planted than if more space per plant is available. In detailed studies involving small numbers of plants in which the lowest variation reasonably obtainable among plants is important, spacing 18 to 20 inches in the row is indicated as preferable to 10 to 12 inches. This is not a recommendation for commercial practice.

4. The best commercial stocks (probably pure lines) exhibit yield variations not significantly greater than certain known pure lines. Several pure lines were observed in which small but significant differences in variability existed.

5. Plots of 300 square feet under reasonably good field conditions, may normally be expected to show a non-correlated variation of about 10 per cent.

6. The coefficient of variability of single plant yield in very small plots (one 20-foot row) with plants 1 foot apart or closer, is very high, generally between 40 and 80 per cent, but sometimes higher. In 100-foot rows this variability in these studies was less extreme. Wider spacing tends to reduce plant yield variability.

Pyrethrin I Content of Strains of *Pyrethrum cinerariaefolium*

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IN the fall of 1928, pyrethrum seed secured from Dr. H. Faes of Lausanne, Switzerland, was sown by the author at the Experiment Station, Gainesville, Florida. During the following May, plants from this seedling were used in establishing several quarter-acre plots in Pennsylvania. Open pollinated selections from these plantings were made in 1931 and 1932 on the basis of toxicity, time of bloom, yield, upright stems, etc. Increase plots (50–200 plants set 30 by 15 inches) of the most promising strains were established at Belleville, Pennsylvania, in 1933, and the pyrethrin I content determined in 1935.

Flowers for testing were picked from every fifth plant in each plot and care was exercised to have representative lots with the disc florets three-fourths open. The Seil modified Tattersfield method (1) of analysis was used and the analyses were made in the laboratories of Stanco, Inc., Bayway, New Jersey. The data are presented in Table I.

TABLE I—PYRETHRIN I CONTENT OF SELECTED STRAINS OF PYRETHRUM

Strain	1935 Analysis Air Dry Basis Per Cent Pyrethrin I Flowers	Per Cent Pyrethrin I Stems
1-31	.58	.021
2-31	.69	.039
3-31	.81	.044
5-31	.72	.041
6-31	.61	.039
10-31	.60	.038
47-32	.59	—
49-32	.66	—
51-32	.63	—
73-32	.62	—
75-32	.60	—
96-32	.68	—
124-32	.68	—
125-32	.65	—
135-32	.85	—
161-32	.77	—
218-32	1.02	—
219-32	.67	—
223-32	.67	—
231-32	.64	—
241-32	.75	—
244-32	.72	—

Laboratory tests in 1928 and 1929 showed that the pyrethrin I content was an accurate basis for estimating the toxicity of kerosene extracts of pyrethrum flowers. Therefore, the primary object of our

¹Pyrethrum Fellow with the Crop Protection Institute, September 15, 1927 to August 15, 1936.

plant breeding efforts has been the isolation of strains of pyrethrum containing a high percentage of pyrethrin I. Good flowers imported from Japan and Dalmatia analyze 0.30 to 0.50 per cent pyrethrin I. As the pyrethrin I content of the selections in this study runs from 0.58 to 1.02 per cent, it is evident that flowers of superior quality can be grown in the United States.

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The Morphology and Anatomy of the Dahlia Seedling

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THIS is a preliminary report of studies being conducted on the anatomy and morphology of the seedling and root system of the garden dahlia (*Dahlia pinnata*, Voss). In this study the variety Unwin's Dwarf Hybrids was used most, although the results were checked with several other varieties. The seedlings were grown in the greenhouses of the Ohio Experiment Station during the summer and fall of 1936. Seedlings of various ages were used in this study, but those 10 to 14 days old proved the most satisfactory for studies of the primary body. At this stage the primary tissues were differentiated but no secondary thickening was present. The specimens were usually fixed and dehydrated in a butyl alcohol series, embedded in paraffin, sectioned according to the usual method, and stained with safranin and fast green.

MORPHOLOGY OF THE SEEDLING

The upper extremity of the primary root of the seedling is characterized by the constriction or smaller diameter of the root in contrast to the hypocotyl. The root system of the seedling is composed of a primary root and several laterals. With the exception of the upper portion of the primary none of these was found to become "storage roots", even in the older plant. The hypocotyl is usually $1\frac{1}{2}$ to 2 cm in length and often gives rise to lateral roots. The cotyledonary node and origin of the cotyledons marks the upper terminus of the hypocotyl. The cotyledons are spatulate, netted-veined, sessile, and photosynthetic. The epicotyl is located in a cotyledonary tube which extends 1 to 2 mm above the cotyledonary node.

ANATOMY OF THE ROOTS

The primary xylem of the young primary root is tetrarch; no exceptions to this were found. As usual the xylem and phloem are radially arranged. There are two to four cells in each of the four protoxylem groups which are abaxially arranged with respect to the six to eight metaxylem vessels. A pith composed of five to 10 cells (as seen in cross section) of parenchyma extends from the hypocotyl to 2 to 4 mm into the primary root. No pith was found in the remainder of the primary root or in its lateral roots. The primary phloem is composed of sieve tubes, companion cells, and parenchyma.

The pericycle is composed of one to two layers of rather irregularly shaped parenchymatous cells. Lateral roots originate from the pericycle opposite the protoxylem points in all instances noted. The endodermis is easily recognizable, although the Casparian thickenings are relatively inconspicuous. The cortex is composed of six to 10 layers of irregular parenchymatous cells. The epidermis is one layer in thickness. No fibers are associated with the primary body.

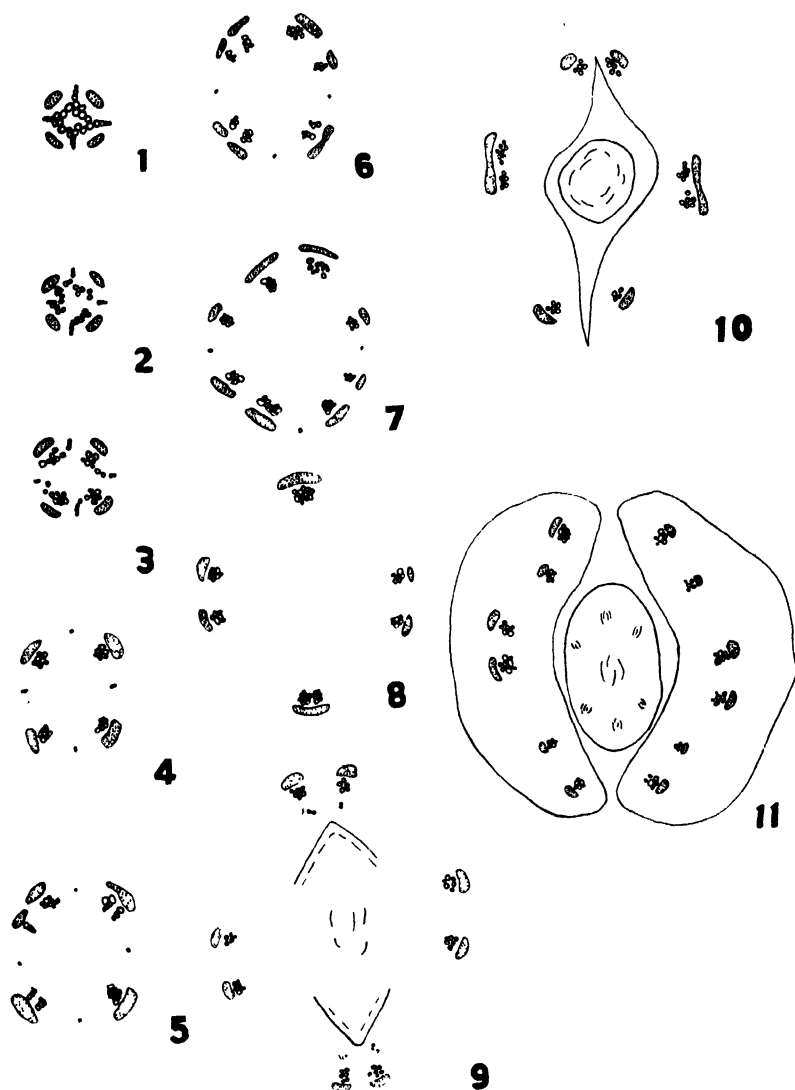


FIG. 1. Partially diagrammatic representation of the primary vascular system in series from base of hypocotyl into the cotyledons. Phloem, stippled.

ANATOMY OF HYPOCOTYL, COTYLEDONARY NODE, AND EPICOTYL

The transition from root to stem structure is located in approximately the lower three-fourths of the hypocotyl. Most of it is in the lower one-fourth or within 4 or 5 mm of the root. The various anatomical changes are given here, beginning with the base of the

hypocotyl and continuing through the cotyledonary node into the cotyledons.

Throughout approximately the lower three-fourths of the hypocotyl the primary phloem is not reorientated but remains in the same relative position as found in the root. A reorientation of the primary xylem, however, is found near the base of the hypocotyl. There the metaxylem is differentiated nearer and in a more nearly adaxial position with respect to the phloem, Fig. 1, (2 and 3). At 4 to 6 mm above the base of the hypocotyl the bundles are collateral and the xylem is nearly endarch, Fig. 1, (4). Often, however, throughout about one-half of the hypocotyl, from one to three cells of the protoxylem, as seen in cross section, remain in the same relative positions as found at the base of the hypocotyl and in the root. The lateral roots, which often arise from the hypocotyl, originate in the pericycle opposite these protoxylem points that remain between the bundles. The pith becomes increasingly larger as a higher level is reached, and is composed of 20 to 30 thin-walled parenchymatous cells as seen in cross section at about midway up the hypocotyl.

At 4 to 5 mm below the cotyledonary node the pith is composed of from 30 to 40 cells as seen in transverse section and the four collateral bundles are endarch, Fig. 1, (5). The few protoxylem elements may or may not be present between these bundles, the pericycle is unchanged, and the endodermis is more indistinct and irregular than below. At about this level each bundle bifurcates; thus eight bundles are present at 3 to 4 mm below the cotyledonary node, Fig. 1, (6). Two of them on each side of the hypocotyl are developed closer and closer to each other, and at a slightly higher level they usually form two opposite bundles, reducing the total number to six. At the cotyledonary node these double bundles are again separate and diverge into the cotyledons, forming the four lateral bundles of the cotyledons—two in each cotyledon. Near the base of the cotyledons each of these bundles bifurcates again, hence throughout most of the cotyledon there are four of these lateral bundles, Fig. 1, (8, 9, 10, and 11).

The other four bundles present in the upper hypocotyl remain in groups of two on opposite sides of the hypocotyl as well as in the same relative positions in the cotyledons. These four are more closely associated into two pairs, however, in the cotyledons and form the midribs of the two cotyledons, Fig. 1, (8, 9, 10, and 11).

It may be noted that the bundles in the epicotyl are not continuous with those of the hypocotyl and root in the primary structure. The endarch collateral bundles of the epicotyl are formed, however, very soon after those just described and are continuous with those of the hypocotyl in the older plant.

Studies of the Keeping Qualities of Cut Flowers

By ALEX LAURIE, *Ohio State University, Columbus, O.*

THE sporadic attempts by a number of workers to influence the keeping quality of cut flowers were based in the past largely on the reduction of bacterial decomposition of the stems submerged in water. Disinfecting chemicals and cutting of the basal portions to eliminate clogging of the conducting vessels were relied upon. Ratsek (1) showed that copper containers aided in keeping qualities and ascribed it to the disinfecting action of copper released from the walls of the containers. Decker (2) indicated that flowers cut under water lasted longer, presumably due to the elimination of air from the conducting vessels. Hitchcock and Zimmerman (3) pointed out that low temperatures and high humidity were factors in prolonging the life of cut flowers. Thornton (4) showed that roses keep longer when stored at low temperatures with a high carbon dioxide content.

The studies at Ohio State University were started in 1934 in an attempt to clarify the present conceptions and to study, not only the effect of various chemicals as disinfectants, but as aids in water absorption and as agents in reducing the respiratory activities. Further studies were made to determine the place and rate of water absorption as well as the rate of respiration.

RESULTS

The Effect of Copper:—Copper containers, copper wire, copper shavings, copper shot and brass shot were used in the tests. The results obtained indicate that the prolongation of life of cut flowers as affected by copper varies with the type of plant used. One group included those which kept 1 to 2.7 days longer than controls. In this may be placed Aster, Godetia, Clarkia, Daffodil, Stocks, Snapdragon, Annual Chrysanthemum, Calendula, Nemesis, Pansy, Marigold, Salpiglossis, Boston Yellow Daisy. The second group showed no apparent difference in keeping quality between controls and copper containers. In this group may be placed Schizanthus, Rudbeckia, Leptosyne, Myosotis, Feverfew, Centaurea, Penstemon and others. In only one instance has copper proven detrimental—the carnation, in which case the length of keeping was reduced by one day. The determination of copper content showed that 1.25 ppm were present, which was found to increase to 1.6 ppm when the containers were cleaned with sulphuric acid. When copper wire and copper shavings were used the copper content increased to 2.23 ppm. This added amount showed slight increases in keeping qualities. However, for practical purposes the use of copper wire in glass containers has a distinct advantage over the copper containers.

Effect of Cutting Stems Under Water:—The effect of cutting stems under water as compared with those cut in the air likewise varies with the plant used. Those which were aided by being cut under water were Snapdragon, Carnation, Sweet Pea, Boston Yellow Daisy, Aster, Annual Chrysanthemum, Marigold, while Calendula and Stocks showed

no difference in effect. Anatomical studies of the stems showed a direct correlation in this respect between stems with large conducting vessels and those with small, the former being benefited less by the under water cutting.

Absorption of Water by Cut Flower Stems:—The common belief is that flowers keep longer in deep water than in shallow, presumably based on the assumption that absorption takes place all along the stem. A series of tests were made with numerous replications, placing flower stems in different depths of water ranging from $\frac{1}{2}$ inch to 10 inches. These tests showed that all cut flowers tried kept as well in shallow water as in deep; in many instances shallow water treatment increased the keeping qualities by 2 to 3 days. In this group may be included Snapdragon, Carnation, Pansy, Aster, Boston Yellow Daisy, Annual Chrysanthemum, Daffodil, Salpiglossis, Godetia, Coreopsis, Delphinium, Cosmos, Hunnemanian. The explanation of these results lies in the fact that less surface is exposed to bacterial decomposition in the water and that absorption takes place from the base of the stem as indicated in the next series of tests.

Place and Rate of Flower Absorption:—Using a mixture of $\frac{1}{3}$ vaseline and $\frac{2}{3}$ paraffin the stems of various cut flowers were (a) sealed completely, (b) along the sides, and (c) the base only. Control plots were not sealed.

Table I shows that in most cases the greater portion of the water is absorbed through the cut end of the stem. The stems which were sealed along the sides absorbed more water and lasted slightly longer than

TABLE I—ABSORPTION OF WATER THROUGH THE STEMS OF CUT FLOWERS*

Crop	Stems Sealed Entirely		Stems Not Sealed		Base of Stem Sealed		Side of Stem Sealed		Temperature (Degrees F)*
	(Cc)	(Days)	(Cc)	(Days)	(Cc)	(Days)	(Cc)	(Days)	
Pansy	0	1	2.6	3	.16	1	2.5	4	65-70
Carnation . .	0	3	8	6	.8	3	7	6	65-70
Snapdragon . .	0	1	14	4	.8	1	15	4	65-70
Boston Yellow Daisy	0	1	4.3	6 7	1	5	3	6	65-70
Sweet Pea	0	1	1.3	3	.4	1	1.5	4	65-70
Cosmos	0	1	3.0	4	.13	1	4	4	75-80
Gaillardia	0	1	4.1	4	.16	1.0	4.3	4	75-80
Delphinium	0	1	21	5	.8	1	23.5	4	75-80
Larkspur	0	1	3.0	4	.9	1	7.5	5	75-80
Chrysanthemum									
Leucanthemum	0	1	8.6	6	1	1	10.6	6	75-80
Iris	0	1	37	7	12	3	40	7	75-80
Aster	0	1	18	8	3	2	17	8	75-80
Rose	0	1	8.0	4	1.0	1	7	4	75-80
Tritoma	0	1	33	5	1	1	42	5	75-80
Calendula	0	1	6.0	6	1	1	4	3	75-80
Hunnemanian	0	1	3.0	3	3	3	3.2	3	85-100
Rudbeckia	0	1	20	4	1	1	23	4	85-100
Zinnia	0	1	50	4	1	3	54	4	85-100
Trachelium	0	1	10	4	1	1	18	4	85-100
Nasturtium	0	1	2.0	3	1	1	1.5	3.0	85-100

*Number of flowers tested was 30 to 100 for each variety.

those which were not sealed at all. The most probable explanation is that in the sealed sides bacterial action was reduced with attendant greater absorption and longer keeping quality.

Rate of Respiration.—The rate of respiration has a bearing on the length of life of cut flowers. To determine the respiration rate measurements of the carbon dioxide evolved were made by the carbonate precipitate method.

TABLE II—RATE OF RESPIRATION OF CERTAIN CUT FLOWERS

Crop	Number of Cc of CO ₂ Evolved per Hour
Aster.	.0089
Boston Yellow Daisy	.01426
Carnation.	.0285
Pansy	.3772
Snapdragon	.018

This table is but an indication of possible trends. Pansy shows the greatest amount of CO₂ given off per hour, while the aster shows the least amount. The keeping qualities of the pansy are proverbially low while those of the aster are correspondingly long. Hence the respiratory rate seems definitely related to the longevity of the cut flower stem and is inversely proportional to the keeping rate.

Effect of Chemicals on Respiration.—Tests were made in an effort to slow up the metabolism of the plant by artificially lowering the respiration rate. Materials were sought which would decrease bacterial action, increase absorption and transpiration, provide the proper hydrogen-ion concentration and osmotic pressure. Of the many materials tried only three showed any effect on cutting down the respiratory rate, hydrozene sulphate, fluroglucinol and resinol. Sodium amytol was effective on sweet peas presumably because of its coagulative action of proteins. Further preliminary studies indicate that combinations of hydrozene sulphate, copper sulphate, sucrose, sodium amytol and metallic zinc powder in proper concentrations may control the factors responsible for keeping qualities of cut flowers; namely, reduction of bacterial activity, increase of transpiration, lowering the rate of respiration and providing the most suitable pH and osmotic pressure.

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A Genetic Study of *Tropaeolum*¹

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THE data included in this report have been compiled after observing the results of an interspecific cross between *Tropaeolum majus* var. Golden Gleam (female) and *T. peltophorum fimbriatum* (male).

The F_1 plants were selfed to produce an F_2 generation and then backcrosses were made between both F_1 and F_2 individuals and the parents. Since however the backcross populations at the time of this writing are not very large only F_1 and F_2 data are recorded herein.

THE LEAF

Shape.—The parents of the cross represent two distinctly different types of leaf shape. Golden Gleam has the simple, entire marginal, peltate, nearly orbicular leaf which is characteristic of the *majus* type. *T. peltophorum fimbriatum* has, on the other hand, a leaf which, while the same in basic shape, has a very distinctly lobed margin. (See Fig. 1, A and B).

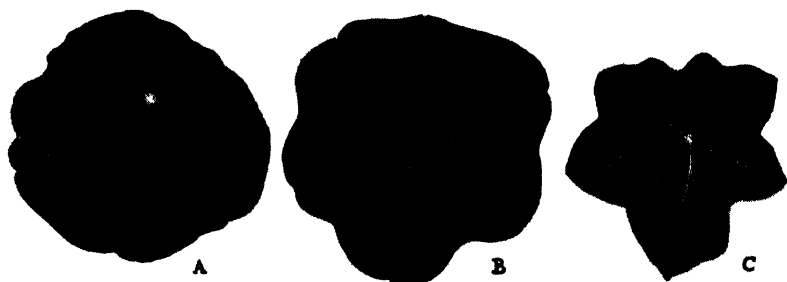


FIG. 1. Leaf Types: A, The non-lobed leaf of *T. majus*. B, The lobed leaf of *T. peltophorum fimbriatum*. C, The undulate type appearing in the F_2 generation.

The leaf of the F_1 hybrid varies very little from the female parent in shape except that it lacks any evidence of the wavy character which is sometimes seen in the margin of Golden Gleam. The above observation indicates that the lobed type of leaf is definitely recessive to the simple or non-lobed type.

This conclusion is supported by the appearance in the F_2 generation of 83 individuals which exhibit the *majus* type of non-lobed leaf to 32 individuals which exhibit the *peltophorum* type or lobed leaf. Tested by the Chi Square method for goodness of fit the observed distribution of 83:32 gives a probability of .49 for a 3:1 ratio.

¹Contribution No. 263 from the Massachusetts Agricultural Experiment Station.

There is in the F_2 population, however, a type which is not like either parent or the F_1 hybrid. The lobes of the leaf are more deeply cut, more pointed and on the whole give the leaf much more of an undulate than a lobed character. (See Fig. 1, C.) In number these individuals make up seven of the 32 individuals classified as lobed; thus there is a modification of form within the lobed type which gives a distribution of 25:7 with the lobed type predominating. The probability for goodness of fit to a 3:1 ratio is .69.

Further inspection of the condition reveals that the observed distribution of 83:25:7 fits a 12:3:1 ratio with a p value of .71. Conformation to this ratio leads to the assumption that there are two genes present, one of which is epistatic to the other. Accepting this assumption as a possible explanation, the scheme of genes may be represented as follows:

L U—Non-lobed
L u —Non-lobed
l U —Lobed
l u —Undulate

Color.—Rasmuson (4) states that "dark green color in the leaf is determined by two genes, the absence of either of which results in a green (medium green) type". He found further that green is dominant to yellowish green and that both medium green and dark green are dominant to yellowish green; also that both are dominant to the variegated condition, which is a green-white mosaic type not found in this experiment.

Both Golden Gleam and *Tropaeolum peltophorum fimbriatum* have leaves of the medium green or, according to Rasmuson's classification, green color. The F_1 hybrid produces leaves which are of an entirely different color from those of the parents. Removal of the epidermal layer and alcoholic chlorophyll extractions show definitely that the hybrid leaf is darker than the leaf of either parent.

The F_2 population shows a great range of leaf color both as to intensity of the green color, and as to different tones of green. The most reasonable way of classifying the colors for the purpose of this experiment seems to be according to intensity. This classification gives a distribution of 60 dark green; 49 medium green; and six light green. Tested for goodness of fit to a 9:6:1 ratio the value of p is .52. Considering the size of the population this value of p is probably high enough to indicate a fairly good fit.

This conformation to a 9:6:1 ratio seems to lend support to Rasmuson's theory concerning the dominance of dark green over medium green, and of medium green over light green. The condition appears to indicate a case of mutually supplementary factors. The genes involved may be represented as:

G G'—Dark Green
G g'—Medium Green
g G'—Medium Green
g g'—Light Green

THE FLOWER

Stem color:—Red stem color due to the presence of anthocyanin is found in the male parent, but is not exhibited in Golden Gleam. The F_1 hybrid shows red color in the stems, but in lesser degree than does its male parent. The F_2 generation contains 86 red-stemmed and 29 green-stemmed individuals. This two-class distribution conforms to a simple 3:1 ratio with a p value of .96.



FIG. 2. Flower Petals: A, The petals of *T. majus* Golden Gleam, showing proliferation of both upper and lower petals. B, The petals of *T. peltophorum fimbriatum*. C, The petals of the F_1 hybrid.

The observations tend to show some degree of difference in the intensity of red exhibited by different individuals. However, because of the difficulty of making correct classifications according to the intensity of the red color, no attempt has been made to segregate the individuals into classes. The presence of red stem color as opposed to the green stem appears to result from simple monogenic inheritance in which the gene for the presence of red is dominant.

Petal number:—Recent studies by Eyster (1) and Eyster and Burpee (2) have indicated that increased petal number (Golden Gleam type of double) caused by greater proliferation of the lower petals than of the upper petals is recessive to the single or five-petaled type. The results of this experiment indicate that the increase in petal number is due to proliferation of both upper and lower petals, but support the contention that increased number is recessive to the five-petaled type. The F_2 distribution of singles to doubles is 86:29, which conforms to a 3:1 ratio with a p value of .96.

Petal type:—The parents represent two extremely different petal types. Golden Gleam flowers have large rounded petals which are characteristic of the majus species; hence for purposes of this paper the designation of "majus type" petal is used. The male parent has a serrate or fimbriate petal, which is designated herein as the serrate petal type (See Fig. 2, A and B). The F_1 hybrid has petals of the majus type, thereby indicating that this type is dominant to the serrate type. The F_2 plants show 84 individuals with majus petals and 31 with serrate petals. The deviation from expected distribution according to a 3:1 ratio is not significant, the value of p being .64, thus indicating simple monogenic inheritance.

Flower color:—Rasmuson (4) states, regarding flower color, that there is a monogenic difference between light and dark yellow, both being due to plastid pigments; likewise between red anthocyanin and its absence. The homozygotes are dark red and the heterozygotes are light red. Also, variegated flowers are dominant to self-colored types. Eyster and Robinson (3) found that the anthocyanin colors are "more or less epistatic" over the plastid colors. The results of the present experiment seem to support these views but throw further light on the inheritance of yellow color.

An explanation of the nature of the colors may make the condition more easily understood. There is a pale yellow color produced by the presence of small plastids, which by microscopic inspection of petals from which the epidermis has been removed, appear to be present in every petal, regardless of its apparent color. Then there is a larger yellow plastid which when present produces a pure, but much darker yellow color than the smaller plastid.

Red color is produced by the presence of soluble anthocyanin in the cell sap. Its degree of intensity appears to depend upon whether or not it is present with the pale or dark yellow plastid. When present with the pale yellow pigment it produces a dark red color but when present with the dark yellow pigment it produces a lighter orange red type.

There is also a spotting condition in which yellow petals have small red areas at the base. In this experiment spotted flowers sooner or later always became flushed. Flushing is a condition in which a petal appears partially yellow and partially red. It is due to incomplete concealment of the yellow by the red color. The degree varies from a minute red area to areas where only the claw fringe remains yellow. The degree of flushing varies with some environmental factor, probably either temperature or light. Observations have not yet proceeded far enough to justify any definite conclusions on this subject.

The distribution among the yellow flowers in the F_2 population of this experiment is 27 dark yellow and two pale yellow. This distribution gives a p value of .89 for conformation to a 15:1 ratio. On the basis of these results the expression of yellow color may be assumed to be controlled by duplicate factors; therefore only the double recessive results in the expression of the pale yellow color. It must be realized that yellow color is present in all of the F_2 individuals but that its expression is concealed by the presence of red anthocyanin.

The distribution in regard to red color in the F_2 population is as follows: 32 solid red, 54 flushed red, and 29 non-red. This distribution gives a p value of .96 for conformation to a 3:1 ratio, assuming a monogenic difference between the presence of red color and its absence. Tested further for agreement with the expected distribution of a 1:2:1 ratio the F_2 distribution gives a p value of .75. This indicates that the flushed condition is exhibited by those individuals which are heterozygous for the gene controlling the presence of the red color.

Combining the two ratios, 15:1 for the expression of yellow, as dark or pale, and 1:2:1 for the red color as dark, flushed, or absent will produce, theoretically, the following ratio: 16 solid red; 32 flushed; 15 dark yellow; one pale yellow. The observed distribution in the F_2 population is: 32 solid red; 54 flushed; 27 dark yellow; and two pale yellow. Tested for goodness of fit the observed distribution gives a p value of .89.

On the basis of the foregoing, the following assumption is made regarding the action of genes controlling the expression of flower color: Λ_n representing the gene for red, a_n as its allelomorph, more or less obscures the expression of Y and Y' duplicate genes for dark yellow, and y and y' as their respective allelomorphs for pale yellow.

LINKAGES

Weiss (5) reported finding three characters "apparently definitely linked"—length of leaf stalks, absence of anterior petal fringe, and sterility (female). Eyster and Robinson (3) state that the genes for yellow foliage and dark maroon flower color are in the same chromosome. Neither of these investigators give any definite distributions or crossover values.

The results of the present experiment indicate two other cases of linkage. The segregation in the F_2 generation suggests linkage between red stem color and red flower color in the coupling phase with a crossover value of $5.00 \pm .014$ per cent (6). Also, non-lobed leaf type seems to be linked with rounded petal type with a crossover value of $6.04 \pm .015$ per cent for the coupling phase. In this latter case the linkage must be between the gene L for leaf shape and the gene for petal shape, as gene U for leaf shape and the gene for petal shape are in the repulsion phase in the parents.

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Easter Lily Breeding: Compatibilities in *Lilium longiflorum* Stocks

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SEEDLING lilies, as far as now known, are free from seed borne virus infection. The advantage of a seedling start in developing commercial stocks is therefore obvious. Various workers are now attempting to develop disease-free garden lilies from seed. In the Easter lily, *Lilium longiflorum*, virus diseases in bulbs that are forced occasionally cause loss to florists. Some commercial stocks are also variable in such characters as height, time of bloom, forcing response, flower color, and size. The work reported in this paper was started in 1935 at Beltsville, Maryland, and Baton Rouge, Louisiana, as part of a general program designed to develop improved, disease-free *L. longiflorum* seedlings. These, when available, can be propagated vegetatively and should give rise to uniform strains. The authors wish to emphasize that the results presented here are only preliminary, but certain interesting trends are indicated.

MATERIALS AND METHODS

The stocks used included the Japanese Erabu and Giganteum of commerce; tall and short types of the Creole lily from Louisiana; an Easter lily in commercial culture in Oregon, herein called Croft, from the name of the grower; a taller type appearing as a mixture in a commercial stock of Croft; a variety called Floridii by its grower in Florida and on Long Island; and a stock of seedlings grown from open pollinated Croft stock in Oregon. Unfortunately a supply of Harrisii was not available in the past year, but such a stock is included in the 1936 plantings.

The bulbs were grown in 6-inch pots and were forced gently. A series of self and reciprocal cross pollinations were made. All possible combinations were not tested because too few plants of some stocks were available, and the blooming dates of others did not coincide. In all cross pollinations the flowers were emasculated and enclosed in paper bags. Pollen was applied when stigmatic fluid was visible on the stigma. Flowers were left under bags until all danger of contamination from other pollen had passed. Similarly controlled self-pollinations were made with plants in each stock, and in addition a large number of unprotected flowers were pollinated with own pollen. Further trials with the Creole stock were made in the field in Louisiana.

RESULTS

The results of this series of pollinations, shown in Table I, include number of pollinations made, capsules formed, capsules containing seed, and number of seed containing embryos. The data show clearly that all stocks tested produce functional pollen and eggs. Preliminary study

TABLE I—COMPATIBILITY OF *Lilium longiflorum* STOCKS

♀	♂	Tall Creole	Short Creole	Florida	Short Croft	Tall Croft	Erabu	Giganteum	Seedling	Open Pollinated Self
Tall Creole		<i>0/13*</i> 0†	<i>0/12</i> 0	<i>0/10</i> 0	<i>7/12</i> 0	<i>4/4</i> 584 4	<i>12/14</i> 478 10	—	<i>0/10</i> 889 9	<i>3/310</i> 48 1
Short Creole		<i>0/6</i> 0	<i>0/14</i> 0	<i>0/7</i> 0	<i>5/5</i> 439 5	<i>4/4</i> 567 4	<i>6/6</i> 806 6	—	—	<i>1/8</i> 35 1
Florida		<i>0/3</i> 0	<i>0/4</i> 0	<i>0/8</i> 0	<i>3/3</i> 294 3	<i>1/1</i> 240 1	<i>3/3</i> 359 3	—	<i>2/2</i> 284 2	<i>0/2</i> 0
Short Croft		<i>5/10</i> 0	<i>5/10</i> 332 5	<i>12/12</i> 1755 12	<i>0/33</i> 0	<i>7/10</i> 1405 7	<i>7/12</i> 989 7	<i>14/25</i> 1847 14	<i>7/10</i> 1144 7	<i>14/347</i> 997 12
Tall Croft		—	<i>1/1</i> 207 1	<i>1/1</i> 131 1	—	<i>0/4</i> 0	—	—	—	<i>4/9</i> 465 4
Erabu		<i>15/16</i> 1077 15	<i>3/3</i> 61 3	<i>3/3</i> 53 2	<i>10/10</i> 1028 10	—	<i>0/3</i> 0	—	<i>4/4</i> 281 4	<i>26/248</i> 265 26
Giganteum		<i>17/18</i> 2644 17	<i>15/17</i> 1969 15	<i>14/15</i> 1887 14	<i>14/15</i> 2857 14	<i>16/17</i> 2253 16	<i>24/26</i> 3279 24	<i>7/43</i> 297 7	<i>15/15</i> 2632 15	<i>8/15</i> 296 8
Seedling		—	—	—	—	—	—	—	<i>4/51</i> 137 4	<i>95/119</i> 8870 95

*Figures in italics indicate number of capsules formed over number of pollinations made.

†Figures in arabic indicate number of seeds with embryos over number of capsules with good seed.

of pollen tube growth shows that even on self pollination (Tall Creole selfed) the pollen germinates and penetrates part way down the style.

While only Giganteum and Seedling gave seed from controlled self pollination, the negative results with the six other stocks are of uncertain significance since the number of self pollinations was in general small. Although only two of eight stocks yielded seed on controlled self pollination, seven of the eight yielded seed when selfed but not bagged. Since the work was carried out in an unscreened greenhouse it is doubtful whether the open pollinated selfs yielded true selfed seed. These unprotected selfings were more fruitful than the bagged selfings, but the seed set was in general low.

Nearly all inter-stock pollinations were highly compatible. Notable exceptions are the Tall Creole-Short Creole-Floridii combinations, all of which failed to form capsules. The Croft x Creole cross and its reciprocal developed capsules but no viable seeds. The Tall and Short Creole stocks, similar except in stem length, differed in compatibility with the Croft stock. The Tall and Short Croft types, also similar ex-

cept in stature, differed in compatibility with Creole. The Short Creole and Floridii stocks behaved alike in all compatibility relations tested. Giganteum proved highly fertile with other stocks in all combinations tested. Erabu was highly fruitful but set comparatively few seed with pollen of other stocks. All combinations indicated as compatible in Table I have produced seedlings, which are now being grown at Beltsville, Maryland, Baton Rouge, Louisiana, and Charleston, South Carolina.

The trials in the field in Louisiana yielded no seed from controlled selfing of 200 Creole plants, none from interpollinating within a second group of 100 flowers on 43 separate plants, and none from bud pollination of 100 flowers on the same 43 plants of this variety.

DISCUSSION AND CONCLUSIONS

Earlier workers have reported that intercrossing commercial stocks of *Lilium longiflorum* is more successful than selfing. Oliver (4, 5) crossed Harrisii and Giganteum, also *L. longiflorum* x Harrisii and the reciprocal. He mentioned that Harrisii selfed produced a low seed set, and that interpollinating different plants was more effective than selfing. Griffiths (1) reports "Crosses of Harrisii giganteum, Formosum giganteum, and multiflorum giganteum have all produced good stocks, as has also Formosum Harrisii, and even selfed plants have given good results." In 1921 he states that interpollination is successful more often than selfing, and that the seed set of selfed plants is commonly but not always small as compared to the set of crossed plants. In 1930 Griffiths added that *L. longiflorum* commonly refuses to produce seed unless there is a wide variation in the parental varieties.

Stout (6) studied compatibility relation in *Lilium longiflorum* and many other species. He reports relations in the Easter lily similar to those in *L. regale* in which he found nine self-incompatible and one self-compatible in 10 individuals tested. He also grew *L. longiflorum* seedlings to flowering age; many proved to be self-incompatible, a few self-compatible.

As pointed out by Stout (7) the vegetatively propagated lily varieties are made up of one or more clons. A named variety should represent a single clon, but in all probability is usually a mixture of several clons which are closely similar in characters of floricultural interest. When two or more clons are present in a named variety it is possible that interpollinating different plants will sometimes produce seed when selfing individual plants does not. Failure to produce seed on interpollination, as in our experience with the Creole variety, suggests that the same sterility factors are common to the clons present. Clons of different compatibility relations may sometimes be selected out of commercial stocks as in the cases of Tall and Short Creole and Tall and Short Croft.

It is well known that *Lilium longiflorum* includes a number of more or less distinct varieties, some of which are distinguishable on morphological characteristics and are recognized botanically. The data presented here serve to point out that differences in self and cross-compati-

bility occur in the named varieties of commerce and that such differences may occur within commercial stocks.

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Propagation of *Rhododendron* Cunningham's White, by Cuttings

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AMONG the problems confronting the rhododendron grower is that of selecting a hardy understock which is tolerant of alkaline conditions. The use of such an understock for some of the better hybrids would extend the range of rhododendron culture and greatly increase the demand for these plants.

A few rhododendrons are known to be tolerant to alkaline conditions. Cunningham's White has been placed in this group by some growers in England. However, this clonal variety is not altogether hardy and has presented some problems in propagation. According to Bowers (1), Cunningham's White is the result of a cross between *Rhododendron maximum* and *Rhododendron cinnamomeum* and is only slightly hardier than *Rhododendron ponticum*. As grown in northeastern Ohio, plants of this variety have exhibited a greater degree of hardiness. During the winter of 1934-35, 3-foot plants were frozen back more than a foot; however, during the winter of 1935-36 little or no injury was observed. Both winters were extremely cold with temperatures dropping as low as 17 and 22 degrees below zero. The condition of the plant as it goes into the winter, the amount of snow fall and the amount of moisture in the soil, determines to a large extent the degree of injury. Since the extent of the injury, as far as has been observed, has been limited to the top of the plant, it would not prevent it from becoming a satisfactory understock.

Regarding the propagation of rhododendron Cunningham's White, Bowers (1) states, "This clonal variety can be rooted quite readily from cuttings of ripened wood, taken in August and held over winter outdoors in a cold frame, the roots being formed by spring." In another place he states, "cuttings are removed to the older wood and placed in a mixture of sand and granulated peat, in an outdoor cold-frame bed, covered with a glass sash and shaded. They should be kept reasonably moist and the whole frame should be covered with a matting or litter for frost protection after cold weather sets in. They appear to do better in a frame than in a greenhouse. It is said that in Germany the cuttings are taken in November and rooted in sandy soil warmed over a hot water bed. They are rooted in March . . . and may be potted."

Attempts at rooting cuttings of this variety in northeastern Ohio by the usual commercial methods have resulted in a low percentage developing satisfactory roots. Layering has been successful but when the layers are severed from the plant at the end of 2 years they are too large for grafting. A rooted cutting after 1 year's growth in pots or beds makes an ideal size for grafting. Preliminary tests were conducted during the fall and winter of 1934 which gave some leads that determined the methods of procedure followed during the fall and winter of 1935 and 1936 and reported in this paper.

PROCEDURE

Cuttings of varying degrees of maturity were taken early in October and immediately packed in moist sphagnum moss. The importance of selecting healthy cuttings and keeping them fresh and turgid cannot be overestimated. After a day's time en route to Columbus, they were held in cold storage, about 40 to 45 degrees F for 2 to 4 days, after which they were recut, treated and placed in the media as given in Tables I and II. In their preparation no buds were removed from the cuttings. All cuttings were handled in a grafting case located in a north lean-to greenhouse. The temperature of the cases varied from 60 to 65 degrees F. Chemical solutions, where used, were applied to rooting medium with the use of a sprinkling can at the rate of 2 liters per square foot of bench space. Plots without chemical treatments received similar quantities of water. Additional amounts of moisture were not applied to any plots until about the last of February except Plot 7, where additional acetic acid solution was applied at varying intervals as the sand dried out. The frames were covered with glass which was turned each morning to remove excessive moisture.

RESULTS

The data recorded are given in Tables I and II.

DISCUSSION OF RESULTS

Observation of the cuttings and a perusal of the data given in Table I indicates that the 0.05 molecular solution of potassium permanganate applied to the rooting medium was too strong, thereby injuring the cuttings and lowering the per cent rooting. The 0.025 molecular solution likewise appears to have caused some injury in the mixture of sand and peat but not in the peat plot. In the latter case, however, it caused only a very slight increase in the rooting percentage. The sand medium treated with acetic acid gave fair results, especially with the succulent and semi-mature cuttings but was not as favorable as the check plot in the mixture of sand and peat. It is possible to explain the superiority of the check plot in sand and peat over that in peat on the basis of acidity. It may be that the peat moss is too acid for best results. The tendency for peat moss to hold large quantities of water may also be partially responsible for the lower percentage of rooting. There is no explanation of the poor results of the semi-mature cuttings in the sand and peat plot treated with 0.025 molecular potassium permanganate. Disregarding the poor results in this particular case, this potassium permanganate treatment was equal or a little better than the check plot.

The data presented in Table II again indicate the superiority of the sand and peat mixture over peat alone. The influence of treatment of the cuttings placed in peat is of no advantage. However, the potassium permanganate treatment of cuttings placed in the mixture of sand and peat raised the average per cent rooted 14.5 per cent. The influence of the treatment is especially noticeable with the mature cuttings. The sucrose and the combined sucrose and potassium permanganate treat-

TABLE I—INFLUENCE OF CHEMICAL TREATMENT OF THE MEDIA ON THE ROOTING RESPONSE OF RHODODENDRON CUNNINGHAM'S WHITE CUTTINGS (CUTTINGS TAKEN OCTOBER 16, 1935)

Medium	Treatment of Medium	Type of Wood	Number of Cuttings Taken	Number Rooted February 29, 1936	Total Number Rooted June 15, 1936	Per Cent Rooted	Average Per Cent Rooted per Treatment
One-half sand and one-half German peat	Check	Succulent Semi-mature Mature	30 30 30	21 13 12	23 19 13	76.7 63.3 43.3	61.1
	0.05 molecular potassium permanganate, 2 liters per square foot	Succulent Semi-mature Mature	30 30 30	2 2 2	5 5 5	16.7 16.7 16.7	16.7
	0.025 molecular potassium permanganate, 2 liters per square foot	Succulent Semi-mature Mature	30 30 30	18 5 13	24 7 13	80.0 23.3 43.3	48.9
	Check	Succulent Semi-mature Mature	30 30 30	14 17 8	16 18 8	53.3 60.0 26.7	46.7
German peat	0.05 molecular potassium permanganate, 2 liters per square foot	Succulent Semi-mature Mature	30 30 30	5 6 11	6 7 13	20.0 23.3 43.3	28.9
	0.025 molecular potassium permanganate, 2 liters per square foot	Succulent Semi-mature Mature	30 30 30	16 13 11	17 14 12	56.7 46.7 40.0	47.8
	95 per cent acetic acid, 1 part-10,000 H ₂ O 2 liters per square foot	Succulent Semi-mature Mature	40 40 25	22 17 3	27 27 5	67.5 67.5 20.0	56.2
Sand							

TABLE II—INFLUENCE OF CHEMICAL TREATMENT OF THE CUTTINGS ON THE ROOTING RESPONSE OF RHODODENDRON CUNNINGHAM'S WHITE CUTTINGS (CUTTINGS TAKEN OCTOBER 18, 1935)

Medium	Treatment of Cuttings	Type of Wood	Number of Cuttings Taken	Number Rooted February 29, 1936	Total Number Rooted June 15, 1936	Per Cent Rooted	Average Per Cent Rooted per Treatment
One-half sand and one-half German peat	0.05 molecular KMnO_4 for 14 hours.	Succulent Semi-mature Mature	15 15 15	10 6 11	12 9 13	80.0 60.0 86.7	75.6
	0.05 molecular sucrose for 12 hours.	Succulent Semi-mature Mature	15 15 15	10 11 4	11 12 4	73.3 80.0 26.7	60.0
	0.05 molecular sucrose for 12 hours, then 0.05 molecular KMnO_4 for 7 hours.	Succulent Semi-mature Mature	15 15 15	8 7 2	11 12 3	73.3 80.0 20.0	57.8
German peat	0.05 molecular KMnO_4 for 14 hours.	Succulent Semi-mature Mature	15 15 15	8 10 3	8 10 4	53.3 66.7 26.7	48.9
	0.05 molecular sucrose for 12 hours.	Succulent Semi-mature Mature	15 15 15	4 4 7	5 10 7	33.3 66.7 46.7	48.9
	0.05 molecular sucrose for 12 hours, then 0.05 molecular KMnO_4 for 7 hours.	Succulent Semi-mature Mature	15 15 15	10 2 3	11 5 5	73.3 33.3 33.3	46.7

ments appear to have had a favorable reaction on the semi-mature cuttings.

CONCLUSIONS

The conclusions that may be drawn from these tests are: (a) Succulent and possibly semi-mature wood are the most favorable types for cuttings. (b) A mixture of half sand and half German peat provides a more satisfactory rooting medium than German peat moss. This superiority is shown not only in the percentage of cuttings rooted but also in the ease of the removal of the cuttings from the rooting medium. (c) Preliminary tests as well as those reported here indicate that if sand is used as a rooting medium it must be of acid reaction. (d) Chemical treatments of the rooting media as practiced appear of no advantage. (e) Treatment of cuttings with potassium permanganate may be of some advantage especially with mature wood cuttings.

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A Preliminary Report on the Respiration of Souvenir Gladiolus Corms Before and After Curing at Various Temperatures

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THIS investigation was made to study the relative influence of different storage temperatures on the curing of gladiolus corms as measured by respiration. It is assumed here that when suberization is well advanced physiological activity is so reduced that the corms may be considered "cured" and in a resting stage.

Fairburn (1) studied Souvenir corms held at 50, 69.8, and 89.6 degrees F, and reports respiration rates of 27.9, 29.4, and 28.3 mg CO₂ per kg-hour, respectively, on October 18, 1931, and 6.9, 10.9, and 21.3 mg at the same temperatures on February 8, 1932. He also reports that total sugars increased in Topaz corms from 1.3 per cent in November to 8.6 in January at 32 degrees storage, to 4.9 per cent at 41 degrees, and to 2.9 at 50 degrees, and that for Souvenir corms during the same period the total sugars increased from 2.7 per cent to 3.2, 2.7, and 3.0 at storage temperatures of 50, 69.8, and 89.6 degrees, respectively.

MATERIALS AND METHODS

The stock for this experiment was planted at Arlington Farm during the first week of May, 1936. During the summer the flower spikes were removed before seeding. The corms were dug on October 20 and the tops cut back to about 1½ inches.

The respiration apparatus employed throughout the experiment was that described by Haller and Rose (2) in which the CO₂ is absorbed by twice normal KOH solution and measured by titrating against standard 2 normal H₂SO₄ to the phenolphthalein end point and then to the methyl orange end point, the difference between the two end points being the figure used in computing the amount of CO₂. Except where noted the results are based on duplicate samples under each condition. Previous to each test the desiccators were sterilized. Temperatures of 32, 36, 40, 50, 60, 70, and 80 degrees F with respective humidities of approximately 85, 85, 70, 75, 50, 40, and 40 per cent, were used. In all of the respiration studies on No. 2 corms the same sample was used but once, except in series III where some of those stored at 32 and 36 degrees in series I were used.

PLAN OF EXPERIMENT

Main Experiment:—On the date of digging the corms were divided into two general lots. Lot 1, selected at random, was cleaned immediately after digging and remained in common storage during the next 3 days in order to offset, at least partially, the effects of wounding. This lot, hereafter designated as series I, was then divided and placed

in storage at temperatures of 32, 36, 40, 50, 60, 70, and 80 degrees F. Respiration determinations on this series, which may be termed the "before and during curing" series, were started on the following day, the results being obtained between the 4th and 10th days after digging.

Lot 2, later divided into series II and III, was held in common storage for 3 days following digging and then stored uncleaned in shallow trays at temperatures of 32, 36, 40, 50, 60, 70, and 80 degrees F. These corms were cleaned on November 3 (14 days after digging) and remained at the original storage temperatures. Respiration determinations were started on series II November 5 and were run at 32, 36, 40, 50, 60, 70, and 80 degrees until November 11, or from the 16th to 22nd day after digging. This series is designated as the "after curing" group. To deter mold growth about 200 cc of H_2SO_4 of specific gravity 1.23 was used in each of the desiccators at 50, 60, 70, and 80 degrees. This gave a relative humidity at the designated temperatures of approximately 75 per cent.

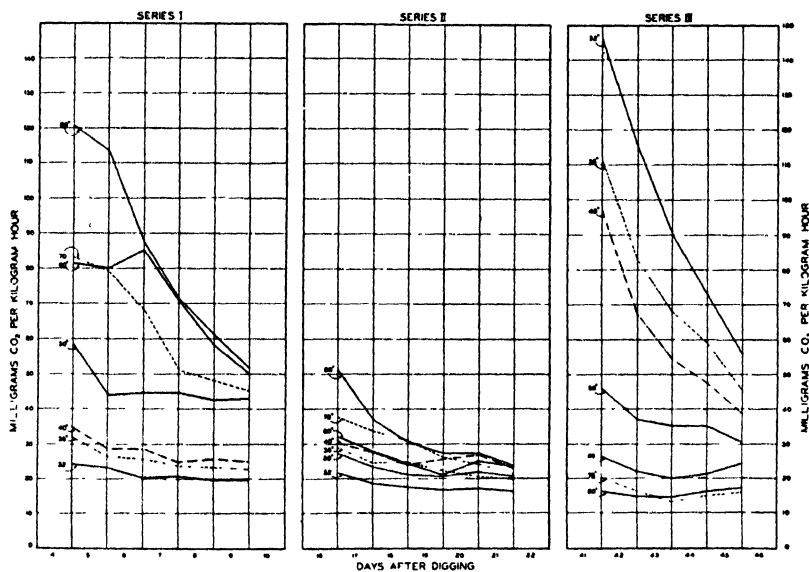


FIG. 1. The daily amounts of CO_2 evolved per kilogram hour in milligrams, during 6-day periods in the respiration of Souvenir gladiolus corms, before and during curing (Series I), after curing (Series II), and at 70 degrees F after storage at various temperatures indicated (Series III).

Series III consisted of corms held at the above temperatures until November 30 when they were all moved to 70 degrees F, the respiration test being started 24 hours later. As these were collected for moving the remaining stems were cut back close to the corms. The results on this series, designated as the "all at 70 degrees group", were obtained between the 41st and the 46th day after digging.

Sub-experiments, Test 1:—To determine the actual increase in respiration due to slight wounding a test was made at 80 degrees F

on material taken from lot 2 at 80 degrees storage. Two samples, lots A and B, were used, neither being duplicated. In lot A the stems and scales were allowed to remain, but these were removed from lot B. This test extended from November 20 to 26, or between the 31st and 37th day after digging.

Test 2:—In order to determine the effect on respiration of extreme variations in storage temperature a test was run on corms from lot 2 held at 70 degrees F from October 23 to December 7, and then moved to 32 degrees. Respiration determinations were started the following day, December 8, and continued for 2 days. On December 10 the corms were removed from 32 degrees and placed at 70 degrees where after 2 hours they came to temperature and the respiration test was started, and continued for 2 days.

RESULTS

In series I (4th to 10th day after digging), as is shown graphically in Fig. 1, there was a general tendency for the rate of respiration at the higher temperatures, 60, 70, and 80 degrees F to drop off rather rapidly. At 50 degrees there was a sudden drop on the second day with a subsequent leveling off until the end of the run. At the lower temperatures of 32, 36, and 40 degrees a gradual decrease was found throughout this series.

Series II (16th to 22nd day after digging) showed a drop in respiration (Fig. 1) through the first 2 days at all temperatures with a subsequent intermingling of the curves for most of the temperatures. It is evident that the rate of respiration for most of the higher temperatures had been dropping between the end of series I and the beginning of series II, but at the lower temperatures a notable increase is indicated between the two series. At the end of series II, or 22 days after digging, the corms at all of the temperatures respired within a range of 16.56 to 23.89 mg CO₂ between 32 and 80 degrees F. respectively.

Series III, Fig. I, plainly indicates a remarkable increase in the respiratory rate at the outset at 70 degrees F for corms previously held at 32, 36, and 40 degrees, as compared with the end of series II, with a subsequent rapid falling off on the succeeding days. These respired more rapidly than the 70 degree corms at the start of series I. The respiration rate of 50 degree corms, as shown on the first day, had increased in this series over those at 70 degrees at the end of series II but were not respiring as rapidly as those at 70 degrees at the beginning of series I. In series III there was a general tendency for the 60, 70, and 80 degree groups to respire at rates fairly close to those at the end of series II.

Sub-experiments, Test 1:—Lot A (stems and scales intact) during the 6-day period at 80 degrees F gave the following daily rates of CO₂: 17.5, 22.7, 19.3, 25.9, 22.3, and 21.6. For the corresponding period lot B (stems and scales removed) evolved 59.3, 34.7, 23.3, 21.9, 19.6, and 19.6 mg.

Test 2:—In the respiration of this sample of corms previously stored continuously at 70 degrees F it was found that when moved to

32 degrees the amount of CO_2 evolved per kg-hour was 2.26 mg which is a 2-day average. One day after being returned to 70 degrees the computed amount was 41.1 mg. On the fourth and last day of this test the amount of CO_2 evolved had dropped to 24.1 mg. The 41.1 mg CO_2 evolved at 70 degrees as described above was practically double the rate at 70 degrees at the end of series II, about the same as at 70 degrees at the start of series II, and approximately one-half of that at 70 degrees at the outset of series I.

A general resume of results should include those in Table I which are presented to show the average initial response during the first 2 days in each series. There was in series I a consistent increase in the amount of CO_2 evolved as the temperatures increased from 32 to 80 degrees F. In series II there was an increase except at 50 degrees where the average was notably lower than at 40 degrees. The percentage decreases between series I and series II at 50, 60, 70, and 80 degrees were much greater than those at 32, 36, and 40 degrees.

TABLE I—THE AVERAGE AMOUNT OF CO_2 EVOLVED PER KILOGRAM/HOUR, IN MILLIGRAMS, FOR THE FIRST 2 DAYS IN THE RESPIRATION OF SOUVENIR GLADIOLUS CORMS BEFORE CURING (SERIES I), AFTER CURING (SERIES II), AND AT 70 DEGREES AFTER STORAGE AT VARIOUS TEMPERATURES (SERIES III)

Storage Temperature (Degrees F)	Before Curing (Series I) (Average of 4th and 5th Day After Digging) (Mgs)	After Curing (Series II) (Average of 16th and 17th Day After Digging) (Mgs)	Decrease Between Series I and Series II (Per Cent)	Original Storage Temperature (Degrees F)	All at 70 Degrees F (Series III) (Average of 41st and 42nd Day After Digging) (Mgs)	Increase of Series III Over the Amount of CO_2 (21.5 mg) Evolved at the End of the 6-day Series II Respiration at 70 Degrees F (Per Cent)
32	23.7	20.3	14.35	32	131.0	508.1
36	29.2	26.8	8.22	36	97.1	350.8
40	31.8	29.2	8.18	40	82.3	282.1
50	51.3	25.5	50.29	50	41.7	93.7
60	80.6	35.0	56.58	60	24.4	13.5
70	81.3	35.8	55.97	70	18.4	-14.4
80	117.2	44.2	62.29	80	15.8	-26.4

DISCUSSION

Fairly consistent results were obtained in series I (Fig. 1) with the exception of those at 50 degrees F where the amount of CO_2 evolved remained nearly constant after the second day. The decrease in rate of respiration at 60, 70, and 80 degrees is thought to have been due to the advancement of the effect of curing or suberization at these temperatures.

In series II (Fig. 1) the 80 degrees F corms gave a determination at the outset slightly too high to conform to the previous general trend. Over the 6-day period between series I and II the corms held at 50, 60, and 70 degrees indicated a steady decline in respiration rate. The rise in respiration between these series at 32, 36, and 40 degrees is

thought to have been due to a slight wound stimulation resulting from cleaning the corms 2 days previous to the start of series II. When series II corms were cleaned at the various temperatures it was noted that those at 32, 36, 40, and 50 degrees were soft and difficult to clean and some wounding probably resulted. At 60 degrees there were a few soft corms but in general these cleaned more easily and better than those at the lower temperatures. Those at 70 and 80 degrees cleaned very well and were noted to be firm and dry.

In this series the tendency toward fluctuation between temperature curves is shown when the general leveling off period occurred. This was to be expected since as was shown by Fairburn (1) even within one temperature a precisely uniform rate was not obtained with *gladiolus* when the readings were taken at intervals up to 18 days. When making daily determinations as indicated here during a leveling off period the possibilities for variation are believed to be considerably extended.

In series III the sudden increase obtained after moving corms from 32, 36, and 40 degrees F to a higher temperature may have been due to previous insufficient suberization, as was found by Artschwager (3) at certain lower temperatures. On the other hand it may have been due to the oxidation of accumulated hexose sugars. However, according to Appleman and Smith (4) the sugar that accumulates in starchy vegetables at low temperatures is not responsible for the initial high respiratory response when these are moved to higher temperatures. Two other possibilities would be a temporary effect due to the sudden increase in temperature as indicated in test 2, or a stimulation due to wounding. The rapid decline in respiration of those from the lower temperatures might possibly have been due to a reversion of sugars to starch. As was previously mentioned the tops had been purposely cut off of all the corms used in series III, 24 hours before the start of this test. At this time it was recorded that the cut stems of those at 32, 36, and 40 degrees were white and much fresher in appearance than those at 50 degrees. The latter, however, did not cut as though dry or dead as was the case with the corms at 60, 70, and 80 degrees. These stems in a more or less fresh state at the lower temperatures may have provided a direct avenue for the rapid exchange of gases until curing advanced sufficiently to retard it. In further support of this may be cited the results of test I which may have been due either to wound stimulation caused by removing the scales and stems from these corms or to permitting a freer interchange of gases immediately following their removal, or both; it can hardly be doubted that these corms were cured after 31 days at 80 degrees.

It is suggested that the determinations on the 50 degrees F corms in series III show merely an intermediate position between the higher and lower temperatures. The respiration rates at 60, 70, and 80 degrees throughout this series continued in practically the same plane, as would be expected when comparing these with the responses as the end of series II.

A general review of the literature reveals responses with other stored products when moved from a low to a relatively high tempera-

ture similar to those obtained here with gladiolus corms. The factors possibly involved in a respiration study of this type might well comprise the following: (a) previous storage temperature, (b) humidity, (c) wounding with subsequent suberization and handling as related to wounding, (d) chemical and physiological changes, and (e) the relationship of these factors to the process of curing.

CONCLUSIONS

There seems to be some respiratory response in cured gladiolus corms due directly to an increase in storage temperature.

The general tendency for the corms at 32, 36, and 40 degrees F to remain practically in the same respiratory plane throughout a 22-day period following digging seems to indicate that they were probably not cured. The reaction of corms at 50 degrees points to an intermediate temperature with respect to curing. The responses at 60, 70, and 80 degrees were similar and may indicate satisfactory curing.

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The Determination of the Normal Date of Bud Formation of Short Day Plants

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OBSERVATIONS and records of the date of flowering of many of the plants which form flower buds and flower under conditions of the shorter days of the year show that this occurs at very nearly the same date each year. Previous work with these plants has indicated that the normal date of bud formation is even more specific than the date of flowering. Temperature and light conditions after bud formation have been observed to affect greatly the time required for flower development after bud formation.

The normal date when day length is proper for bud formation should be the date to start increasing the length of day to delay flowering, or the date after which further short day treatments would probably be of no value in hastening flowering. It might also be of significance in explaining certain results of treatments, such as fertilization and temperature changes, made with respect to the date of bud formation.

The plants treated and found to flower earlier than normal when given short days were: *Chrysanthemum morifolium* (var.), *Callistephus chinensis*, *Piqueria trinervia*, *Euphorbia fulgens*, *Euphorbia pulcherrima*, *Eupatorium coelestinum*, *Bougainvillea spectabilis* var. *Crimson Lake*, *Begonia socotrana* var. *Lady Mac*, and *Kalanchoe blausfeldiana*. The plants were grown in the greenhouse bench in pots or in the field depending upon the common commercial practice. At regular intervals of time during the growing period some of the plants were placed under conditions of day length shorter than normal. Black rubberized or sateen cloth was placed over the plants according to the method previously described (1) at 5 p. m. and removed at 7 a. m. The treatments were given daily after starting until the plants were in full bloom.

The dates at which the buds appeared, the date color showed, and the date of bloom were recorded for each treatment. From these data the normal time when conditions were proper for bud formation was calculated. The work with *Chrysanthemum*, *Piqueria*, *Euphorbia fulgens*, *Eupatorium*, and *Callistephus* has been checked for 3 or more years. Other plants were treated for the first time in 1936. To conserve space, the method of calculating the date when days are the proper length for bud formation is given only for *Piqueria*.

The date of bud appearance and the date color showed are obtained with greater accuracy than the date the flowers are ready to cut. One may calculate the number of days from the date the days were the proper length for bud formation to the date of the appearance of color in the bud. This appears in the last column of the table. The July treatment showed color in 32 days. It is assumed that a high temperature was responsible for this bud development which is more rapid than the later treatments where 38 to 45 days were required. Treatments started September 20 and October 1 in 1935 and 1936 respectively flowered at the same date as those not treated. It is assumed

TABLE I—TIME OF BUD FORMATION OF PIQUERIA AS AFFECTED BY STARTING SHORT DAY TREATMENTS AT SUCCESSIVE INTERVALS

Treatment Started (Date)	Buds Present (Date)	Color (Date)	Ready to Cut (Date)	Days From Treatment to Color
July 15, 1935	Aug. 2, 1935	Aug. 16, 1935	Aug. 30, 1935	32
Aug. 15, 1935	Sept. 7, 1935	Sept. 25, 1935	Oct. 9, 1935	41
Aug. 25, 1935	Sept. 21, 1935	Oct. 3, 1935	Oct. 29, 1935	39
Sept. 10, 1935	Oct. 11, 1935	Oct. 10, 1935	Nov. 15, 1935	39
Sept. 20, 1935	Oct. 15, 1935	Nov. 4, 1935	Nov. 21, 1935	45
Sept. 30, 1935	Oct. 15, 1935	Nov. 4, 1935	Nov. 21, 1935	35
Check	Oct. 15, 1935	Nov. 4, 1935	Nov. 21, 1935	—
Sept. 1, 1936	Sept. 21, 1936	Oct. 8, 1936	Oct. 28, 1936	38
Sept. 15, 1936	Oct. 8, 1936	Oct. 26, 1936	Nov. 13, 1936	41
Oct. 1, 1936	Oct. 16, 1936	Nov. 9, 1936	Nov. 25, 1936	39
Check	Oct. 17, 1936	Nov. 9, 1936	Nov. 25, 1936	—

in this case that the date when the normal day length became proper for bud formation was the same as the date the treatment started, or between September 20 and October 1.

Had one of the treated lots, (*i.e.* September 20), not flowered with the check, the date of bud formation would have been estimated at 38 to 45 days before the color showed, or between September 20 and 27.

It appears that one could check this date by lengthening the day starting at successive times near the date estimated by the short day treatment. This was carried out in 1936. Seventy-five watt Mazda lamps at a distance of 2 feet above the plants were operated for 4 hours each night. Successive treatments were started every 5 days starting September 15. September 15 and 20 treatments did not form buds, while the plot treated starting September 25 formed a few flower buds on the terminal part of the stem. The treatment started October 1 flowered in normal season.

This data also shows that the normal date for bud formation is about September 25.

TABLE II—NORMAL BUD FORMING PERIOD

Plant	Normal Bud Forming Period
<i>Chrysanthemum morifolium</i> (many varieties)	August 15 to 25
<i>Eupatorium coelestinum</i>	July 25 to August 10
<i>Piqueria trinervia</i>	September 20 to 27
<i>Kalanchoe blausfeldiana</i>	September 25 to October 5
<i>Euphorbia fulgens</i>	October 10 to 20
<i>Euphorbia pulcherrima</i>	October 10 to 20
<i>Begonia socotrana</i> (Lady Mac)	October 10 to 20
<i>Bougainvillea spectabilis</i>	September 20 to October 1

Table II shows the normal period when buds form as calculated at Ithaca on the short day plants so far treated.

Plants which are 12 inches or more in height react to length of day the same as *Chrysanthemums*, with the exception of *Callistephus*. Very little vegetative growth occurs during the period when the days

are the proper length for bud formation, and almost no flower buds until the days reach the proper length. Callistephus has been found to form flower buds under any length of day, but produces stem elongation only under long days when the daily temperature fluctuation is between 50 and 70 degrees. Normal stem elongation occurs starting May 1 to 10. A small period of stem elongation is apparently necessary before buds will form.

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Preliminary Studies on Flower Bud Differentiation in Relation to Photoperiodic Response

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THE early work of Garner and Allard showed that some plants could be classified into long and short day groups according to their light requirements. Since that time much has been accomplished to make a practical use of this phenomenon particularly under greenhouse conditions. A study of chrysanthemum flower bud differentiation under normal and short day treatment has been carried on since 1932.

Since the practice of subjecting chrysanthemums to a short day to produce early flowering is becoming more widely followed it is important that we know something about the internal conditions that bring about this change. The data reported here were obtained during the summer of 1936. On May 30, 240 plants of the chrysanthemum variety Silver Sheen, a large white flowered variety, were potted into 6-inch pots, using a well fertilized soil. On July 20 they were divided into two lots, one grown normally with the prevailing light conditions at that time of the year, and the other given a short day treatment. Shading was done with the use of black cloth which covered the plants from 5 p. m. until 7 a. m. This subjected the short day plants to a 10-hour daylight period which was continued from July 20 to August 12 (22 days) at which time the flower buds were about $\frac{1}{4}$ inch in diameter. The terminal flower bud on the normal plants did not become visible until September 15 and was about $\frac{1}{4}$ inch in diameter by September 21. Plants which received the short day treatment flowered September 15 while normal plants flowered on October 20.

Daily microchemical tests of the tip and stem were made on fresh tissue of both shaded and normal plants until the flower bud was $\frac{1}{4}$ inch in diameter. The tests on the shaded plants ran from July 20 to August 12 and on normal plants until September 21. Microchemical tests were made for starch with the Iodine test; reducing sugars with Flückinger's method; nitrates with Nitron reaction and Diphenylamine reaction; protein with Millons reagent; and ammonium with Nessler's reagent. Free hand sections were made of fresh tissue just under the growing tip or bud and about 3 inches below this where the tissue was mature, yet soft enough for hand sectioning. These two portions are referred to in the discussion as tip and stem.

ANATOMICAL STUDIES

Anatomical studies made of chrysanthemum buds taken each day during the period of shading showed that the growing point changed from vegetative to a differentiation of floral primordia within 8 to 10 days after the treatment is begun. Beginning 5 days after shading, two plants were removed each day from the shaded treatment and allowed to flower. From this a series of plants was obtained that showed successive flower bud formation. Plants that were shaded

for 5 to 6 days or less remained in a vegetative state and continued to grow and flower at the same time as the unshaded plants. The plants that were shaded for at least 8 days when removed from the shade treatment continued to develop the flower bud that had differentiated. The buds that were studied from an anatomical standpoint showed that the flower primordia is first visible at 7 days after shading treatment began. The plants that were shaded 6 to 8 days varied in their response, all shaded at least 8 days continued to develop the flower bud and those shaded 6 days or less remained in a vegetative condition until the time for the normal flowering to occur. However, a formation of a so-called secondary bud in the center of the flower took place when the plant was shaded 8 to 20 days. This so-called secondary bud is a bud-like formation of leaf and flower tissue that is probably the crown bud. The plants that were shaded from 8 to 20 days showed a decrease in the secondary bud development and formed well developed flowers if shaded at least 20 days. This is an indication that a change from crown to terminal buds occurs by the end of about 20 days of treatment.

MICROCHEMICAL STUDIES

The results that have been secured are as follows: On August 5 an application of ammonium sulfate was made to all plants and this has a bearing on the results that have been secured and is noted in the discussion. The stem of the normal plant had an abundance of nitrates until flower primordia were initiated on September 5 when it dropped rapidly until only a trace was present. The nitrate content remained low until the flower bud was visible on September 21. In the stem of the shaded plant the nitrate content remained abundant until 10 days after shading when it dropped to a very small amount. This drop occurred 3 days after the initiation of the flower primordia. After the bud became visible on August 6 the nitrate content increased rapidly and remained constantly high, as long as tests were made, due to the ammonium sulfate that had been applied.

Nitrates in the growing point or tip of the normal and shaded plants were absent until an application of ammonium sulfate was made on August 5. Following this fertilizer application there was found a very small amount in the normal tip until the time of flower differentiation when it disappeared completely. In the shaded plant following the fertilizer application a small amount of nitrates were present and remained to August 12 as long as observations were made on the shaded plants.

No starch was present in the normal stem until July 29 when a trace of it was first observed. The starch increased slightly by August 29 and then gradually decreased with flower bud initiation until only a trace was observed at the time the flower bud became visible. The stem of the shaded plant showed no starch until 7 days after shading when a trace was observed with a slight increase by the time the bud appeared. In the tip of the normal plant the starch which was absent at the beginning increased to a relatively moderate amount at bud initiation. Then it gradually fell off until the bud was visible at which time only a trace was observed. Starch in the tip of the shaded plant

was first observed 10 days after shading with only a trace present and increased slightly to the end of the shading period on August 12.

Protein, as measured by Millons reagent, in the stem of both normal and shaded plants, dropped from July 23 until August 5 when an application of ammonium sulfate was made. Following this the protein increased in both types of plants. A similar drop was observed in the tip of the plant but the drop from an abundant amount on July 20 was less noticeable and increased following the fertilizer application.

Reducing sugars in the stem of the shaded plant dropped from an abundance at the beginning on July 20 to none by July 26. This was followed by a slight rise for the remainder of the shading period, or until August 12. There was a small drop in the amount of reducing sugars present in the normal stem but not as great as before. This was followed by an increase to an abundant amount by September 1 and remained until the flower bud was visible. In the tip the reducing sugars dropped to only a trace within 10 days after shading and then increased slightly to the end of the treatment. The tip of the normal plant showed a slight drop within the same period but increased to an abundant amount until bud differentiation when there was a drop to a small amount that remained constant until the bud appeared.

Ammonium tests made on both the shaded and normal plants showed no significant variation in either the tip or the stem. The tests indicated an abundance present in the tips of the plant throughout most of the period of observation from July 20 to September 21. The amount in the stems varied slightly but was the same in both the normal and shaded plant at any time.

A summary of this study indicates that there is very little difference in the protein and ammonium content between the normal and shaded plants in either the tip or stem. Reducing sugars in the tip of the shaded plants were very low during the period of flower bud initiation and increased slightly after the flower bud was formed. In the non-shaded plant reducing sugars were present in a moderate amount at flower bud formation and did not increase after the formation. Reducing sugars were very low in the stem of the shaded plant at the time of the initiation of the flower buds. In the stem of the non-shaded plant reducing sugar was abundant at flower bud initiation. Nitrates in the stem of the shaded plants dropped at 10 days after shading and remained low until the time the bud became visible when they increased rapidly with the application of ammonium sulphate. In the stem of the non-shaded plant nitrates were abundant until flower initiation when they dropped to a slight amount. Nitrates in both normal and shaded plants were absent at flower bud initiation. Starch was absent or present in extremely small amounts in the tip and stem at the time of flower bud initiation in both normal and shaded plants. Anatomical study indicates that flower buds are initiated in the chrysanthemum at 6 to 8 days after the plants are subjected to the shading treatment. Plants shaded between 8 to 20 days showed development of a so-called secondary bud. Plants shaded 8 days showed greatest development of this bud with a lesser development as the plant was shaded for a longer period so that after 20 days of shading the flowers developed normally.

Prolonging the Flowering Period of Chrysanthemums With the Use of Supplementary Illumination

By G. H. POESCH, *Ohio State University, Columbus, O.*

INVESTIGATORS have proven that the greenhouse chrysanthemum is a short-day plant. Laurie and others found that by reducing the length of day in July and August, flowering occurs much earlier than plants treated normally. Knowing the commercial value of this plant, preliminary trials to prolong the flowering period were set up in 1934.

In 1934, a series of nine plots with 70 plants each was conducted. Cordova, Silver Star, Legal Tender, Tonquin and Rolinda were used. Rubberized cloth was used as separation between the various plots. The intensity was varied by the use of various wattage lamps. Plot 1, 15-watt lamps; Plot 2, 25-watt lamp; Plot 3, normal; Plot 4, 40-watt lamps; Plot 5, 50-watt lamps; Plot 6, 75-watt lamps; Plot 7, normal; Plot 8, 100-watt lamps; and Plot 9, 150-watt lamps. The intensity varied from 2 foot candles to 36 foot candles. The lights were started September 17 and discontinued October 28. The period of daily additional illumination was 3 hours.

Applying the light September 17 was too late as the flower buds were differentiated before additional light was used, and a secondary vegetative growth developed. It was also found that even distribution of light was necessary, and that low intensities (2 foot candles) from 15-watt lamps were *not* as effective as 4 foot candles in retarding the flowering.

1935 RESULTS

Varieties blooming ordinarily the latter part of November were selected. Light was applied from 100-watt lamps spaced $7\frac{1}{2}$ feet apart and one line of lamps illuminated two benches so as to give about 2 to 3 foot candles of light at the furthestmost place from the lamp. From the date of starting until September 7, 2 hours of additional light were used, and thereafter until termination lamps were lighted for 3 hours each evening. The plants were planted 8 inches by 8 inches in July. Normal cultural treatment was given.

The results show that all periods of applying additional light were effective in retarding flowering. The production was decreased in all varieties when light was applied from August 26 to October 14. When plants were given additional illumination from September 2 to October 7 the flowering was more irregular, due to the fact that bud differentiation had taken place before the light treatment was started. When lighted from August 5 to September 23, the flowering period was prolonged 2 and 3 weeks over the check with the exception of Orchid Beauty. The plots receiving additional light from August 12 to September 30, and August 19 to October 7 showed retardation of all varieties from 4 to 5 weeks. In the latter plot the cutting period was extended approximately 7 days over the former.

TABLE I—EFFECT OF SUPPLEMENTARY LIGHT UPON THE PRODUCTION AND TIME OF BLOOM OF POMPONS

Time of Additional Light	Time of Bloom	Production Number of Plants Required to Make an 8 Ounce Bunch
<i>Valencia</i>		
August 5 to September 23	December 9 to December 30	3½ plants
August 12 to September 30	December 20 to January 8	2¼ plants
August 19 to October 7	December 20 to January 8	3½ plants
August 26 to October 14	December 20 to January 15	5 plants
September 2 to October 7	December 20 to January 15	5 plants
Check	November 19 to December 9	2 plants
<i>Princeton</i>		
August 5 to September 23	November 29 to December 10	3 plants
August 12 to September 30	December 6 to December 30	3 plants
August 19 to October 7	December 20 to January 15	3 plants
August 26 to October 14	December 2 to December 30	2½ plants
September 2 to October 7	December 9 to January 15	6 plants
Check	November 19 to November 21	2 plants
<i>Rolinda</i>		
August 5 to September 23	December 14 to December 30	4 plants
August 12 to September 30	December 20 to January 10	3 plants
August 19 to October 7	December 14 to January 15	3 plants
August 26 to October 14	December 20 to January 15	5 plants
September 2 to October 7	December 20 to January 15	3 plants
Check	November 19 to November 25	2 plants
<i>Orchid Beauty</i>		
August 5 to September 23	November 22 to November 26	2½ plants
August 12 to September 30	December 6 to January 15	2½ plants
August 19 to October 7	December 1 to January 11	2 plants
August 26 to October 14	December 6 to January 15	2 plants
September 2 to October 7	November 21 to January 15	2½ plants
Check	November 19 to November 26	2 plants
<i>Cordova</i>		
August 5 to September 23	December 6 to December 26	3 plants
August 12 to September 30	December 10 to January 1	3 plants
August 19 to October 7	December 26 to January 14	3¼ plants
August 26 to October 14	December 26 to January 14	6 plants
September 2 to October 7	December 6 to January 15	2½ plants
Check	November 21 to December 14	2 plants

1936 RESULTS

Plots were set up using lamps emitting a large percentage of blue rays. These were used in comparison to the Mazda lamps. The General Electric Company manufactured special 50 watt lamps with blue coatings. These lamps are referred to as medium blue and light blue. In addition, daylight lamps, 40- and 50-watt, mercury vapor lamp, 450-watt, and Mazda 50-watt lamps were used. Two series of seven plots were conducted, one on pompons with Orchid Beauty, Rolinda, Valencia and Princeton, the other on standards with the following varieties: Gladys Pearson, Golden Pearson, Distinction, Garnet King, Mefo, Marie DePetris, Monument, and December Glory.

All the lamps except the mercury vapor lamp were placed directly over the center of the bench with 4-foot centers. The test was started August 10 with 2 hours additional light at sunset each day until September 7, after which 3 hours of additional light were used.

The medium blue and light blue lamp plots were retarded from 4 to 7 days, while the Mazda lamp plot was retarded 28 to 35 days. Daylight lamps, 40- and 50-watt, also were less effective than Mazda lamps. The mercury vapor lamps did retard the plants more than the other plots which received blue light, but again were not as effective as the Mazda lamps. Foot candle readings were made on all plots; the medium blue varied from .4 to 1.4 foot candles, light blue .8 to 2.8 foot candles, daylight 40-watt 2 to 8 foot candles, daylight 50-watt 2.5 to 8 foot candles, Mazda 50-watt 4 to 14 foot candles, and mercury vapor 3 to 40 foot candles. Blue light did not have any effect on shortening the height of the plants.

CONCLUSIONS

Supplementary additional light applied before August 15 and discontinued October 1 was most effective in retarding flower bud differentiation of the chrysanthemum. Mazda lamps installed to emit at least 3 foot candles at the furthestmost point from the lamp were more satisfactory than daylight, medium and light blue, and mercury lamps. Increasing the day length to 15 hours is sufficient to retard flowering. Production of pompons is greatly reduced by retarding the bud formation. The number of flowers per spray was also greatly reduced. Varieties differ greatly in response to this treatment. Standard and disbud varieties can be retarded with greater financial success than pompons. Some of the better varieties were found to be Monument, Marie DePetris, Crimson Glow, December Glory, Orchid Beauty, Cordova, and Rolinda. The strong growing varieties were found most adaptable for use in retarding studies. Plants to be retarded should be propagated in June and planted in July. The last pinch should be made shortly before applying additional light.

Further Responses of Miscellaneous Plants to Temperature

By KENNETH POST, *Cornell University, Ithaca, N. Y.*

MUCH of the earlier work with temperature and flowering of vegetables was carried out or directed by Thompson and is reviewed by him (5). Growth responses of some greenhouse ornamentals to high and low temperature have been reported by Post (2, 3, 4). The response of *Callistephus* was reported by Biebel, Green, and Withrow (1).

The work reported in this paper was carried out in a manner similar to that reported in 1935 (4). The plants treated were: *Calceolaria* (variety James hybrids), *Senecio cruentus* (Cramers hybrids), *Zantedeschia elliottiana*, and *Primula malacoides* (var. Erikssoni). The low temperature house was maintained at 50 to 60 degrees F, and the high temperature house at 60 to 70 degrees F.

RESULTS

Calceolaria:—The seeds of *Calceolaria* were planted August 22. The plants were grown in a sandy loam manure composted soil to which one-fourth by volume of peat and sand were added. They were shifted to successively larger pots as needed and were finally placed in 5-inch pots December 23. Every 10 days five plants were moved from the high temperature house to the lower temperature house. A portion of the average plant blooming dates is given in Table I.

TABLE I.—DATE OF BLOOM OF CALCEOLARIA

From High to Low Temperature (Date)	Average Date of Bloom
November 20	March 24
December 10	April 19
January 1	April 16
January 20	April 29
February 24	May 10

It is evident from Table I that flowering of the *Calceolaria* plants was delayed by the higher temperatures. The flowering of the plants which were kept longer in the high temperature was very erratic in comparison with those which were given a low temperature continuously. Those plants kept at the high temperature during the entire experiment occasionally flowered. Most refused to flower at the high temperature. The data suggests that the high temperature house was on the borderline of temperature suitable for bud formation.

Cinerarias:—The seeds were planted and the plants cared for in the same manner as *Calceolarias*. The results appear in Table II.

Fifty per cent of the plants which were given high temperature all the time flowered, most of them during May. The data show that high temperature delayed flowering and prevented it in some cases. The

TABLE II—DATE OF BLOOM OF CINERARIAS

From High to Low Temperature (Date)	Average Date of Bloom
Low temperature—all times	February 15
November 10	February 26
December 1	March 12
January 1	March 25

hybrid cineraria is a very variable species and it is thought that the temperature was not maintained at a sufficiently high level to prevent flowering in all plants.

Zantedeschia elliottiana:—Many greenhouse men attempt to force Yellow Callas at low temperatures. If they do not grow them to maturity at the lower temperature, they frequently start at a low temperature for rooting. On November 20, 30 roots of Yellow Calla were potted in composted soil in 5-inch pots. Eight were placed in each 50, 60, and 70 degree minimum temperatures on the greenhouse bench. The dates at which the first flower appeared on each plant are in Table III.

TABLE III—DATES OF FLOWERING OF YELLOW CALLAS

Temperature (Degrees F)	Date of First Bloom
70	February 11
60	February 28
50	May 10

Observation of the plants at the low temperature showed that no growth occurred until the outdoor temperature increased to such an extent that it was impossible to keep it below 60 degrees in the greenhouse. It is quite evident that very little root or top growth occurs until the temperature reaches 60 degrees F.

Primula malacoides:—The seeds were planted November 22 and the plants were placed 2 x 2 inches in 2½-inch flats January 6. They were kept here until the leaves began to crowd. February 24 the plants grown at the high temperature began to crowd and were placed in 3-inch pots. Those at the low temperature did not become large enough to require potting. The addition of one plot which was given 5 hours of additional light per day of an intensity of 20 to 30 foot candle intensity was made. The light was turned on during the middle of the night. The results appear in Table IV. Seventy plants were used in each treatment in the cold house and 20 in each treatment in the warm house.

TABLE IV—EFFECTS OF DAY LENGTH AND TEMPERATURE ON PRIMULA MALACOIDES

Treatment (Degrees F)	Average Date of Bloom
50 to 60	March 27
50 to 60 (light)	April 6
60 to 70	April 4
60 to 70 (light)	

Table IV shows that lengthening the day delayed flowering at the low temperature and prevented it at the high temperature. The higher temperature delayed flowering but did not prevent it. The plant was either prevented from flowering due to the long day and high temperature, or the effects of the additional light were to increase the temperature of the plant sufficiently to prevent flowering. In the latter case a slightly greater temperature than was maintained should prevent flowering.

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Effect of Alternating Temperature on the Flowering of Lavender Column Stocks

By KENNETH POST and ROBERT S. BELL, *Cornell University, Ithaca, N. Y.*

A NUMBER of experiments were conducted to find what effect daily or hourly fluctuation of temperature from 50 degrees F to 65 degrees F would have on the flowering of lavender column stock (*Mathiola incana*). Post (1) has shown that a temperature below 60 degrees promoted the flowering of stocks, while a temperature above 60 degrees tended to prevent it.

One experiment was made to determine how long a temperature of 50 degrees is necessary daily to cause flower buds to form on stocks. The plants were started October 8, 1935 and the treatment started December 3, 1935. The plants used in this treatment were grown at 65 degrees until several lobed leaves had developed. Throughout this paper 50 degrees F means that the temperature was kept as near 50 degrees as possible, while 65 degrees F means the temperature was not allowed to drop below this figure. One flat of 15 plants was used for each treatment, which was given during daylight hours. The following table shows the results of the daily treatment:

TABLE I—HOURS AT 50 DEGREES NECESSARY DAILY FOR BUD FORMATION

Hours at 65 Degrees	Buds Showing	Time of Bloom	Height (Inches)
2	February 18	March 24	30
4	February 18	March 24	28
6	March 20	_____	24
8	_____	_____	19
10	_____	_____	19
Constantly	_____	_____	19
At night	_____	_____	15
Check—50 degrees	February 16	March 24	31

It appears from this experiment that at least 18 hours per day of a temperature below 65 degrees F was necessary for bud formation. More than 6 hours of a temperature above 65 degrees prevented bud formation in column lavender stocks.

The seeds for the following two groups of experiments were planted January 2, 1936, the seedlings potted January 17, and placed either at 50 degrees or 65 degrees F depending on where the plants were to be used. Treatments were started February 3. Fifteen stock plants were placed in each flat. A flat of plants was used in each test. The treatments were discontinued March 24 because of normal high temperatures.

EFFECT OF ALTERNATING PERIODS AT 50 DEGREES AND 65 DEGREES

In order to determine what effect alternating periods of 50 degrees and 65 degrees F would have on the flowering of stocks, flats were exposed to the above temperatures at definite periods as described below.

A series of several flats were used. In each series the number of days at 50 degrees was fixed and the number of days at 65 degrees varied

from 1 to 7. Thus we had 1 cold day followed by 1 warm day, 1 cold day followed by 2 warm days, and so forth, up to 7 warm days. In the next series, 2 cold days to 1 warm day, 2 cold days to 2 warm days, and so forth, were used. The following table shows the alternations and the effect upon bud formation:

TABLE II—EFFECT OF ALTERNATING PERIODS OF 50 DEGREES AND 65 DEGREES

Days at		Days to Bud From February 3	Number Flow- ering of 15 Plants Treated	Period of Bloom
50 Degrees	and at 65 Degrees			
1	1	58	3	April 28 to May 8
1	2 through 7	No bloom		
2	1	47	11	April 23 to May 8
2	2 through 7	No bloom		
3	1	47	10	April 21 to May 2
3	2	58	4	April 28 to May 2
3	3 through 7	No bloom		
4	1	47	15	April 21 to May 2
4	2	53	5	April 23 to May 2
4	3 through 7	No bloom		
5	1	38	15	April 16 to May 8
5	2	38	14	April 21 to May 8
5	3	51	9	April 21 to May 2
5	4	51	6	April 28 to May 8
5	5 through 7	No bloom		
6	1	38	15	April 19 to May 28
6	2	47	15	April 21 to May 28
6	3	47	12	April 21 to May 2
6	4	47	12	April 21 to May 2
6	5	47	9	April 21 to May 2
6	6	47	4	April 21 to May 2
6	7	No bloom		
	Check	38	15	April 16 to May 19

The data in Table II show that a ratio of 1 day at 50 degrees to one at 65 degrees was the lowest ratio at which buds formed in lavender column stocks. If the ratio of 65 to 50 degrees was greater than 1 to 1, stocks failed to flower, but the lower the ratio of high to low the quicker the buds were initiated.

AGE AT WHICH BUDS INITIATE IN LAVENDER COLUMN STOCKS

To determine the age at which buds initiate at 50 degrees, the following treatments were given to seedlings started from seed January 2, 1936. Treatments began February 3, 1936.

Flats containing 15 plants each were moved from a 50 degrees temperature at weekly intervals to a house where a 65 degrees temperature was maintained. Likewise, flats were moved from a 65 degrees house to a 50 degrees house on the same dates.

Table III gives the data on bud formation, and on leaf lobing, which

TABLE III—EFFECT OF TEMPERATURE ON BUD, LEAF, AND STEM DEVELOPMENT

Treatment	Age When Moved to 65 Degree House		Age When Buds Showed (Days)	Days From Bud to Bloom	Number of First Lobed Leaf	Age at Time of Lobing (Days)	Average Height (Inches)	Average Length of Inter Node (Cms)	Average Size of Leaf (Cms)
	Days	No. Buds							
50 degrees to February 3.....	31	None	—	—	26	120	9	2 5/8	15 x 3
50 degrees to February 10.....	38	None	—	—	28	120	11	1 2	16 x 4
50 degrees to February 17.....	45	None	—	—	28	120	11	1 2	16 x 4
50 degrees to February 24.....	52	Buds	70	Aborted	0	0	16	1 1/2	16 x 4
50 degrees to March 2.....	59	Buds	70	Aborted	0	0	16	1 1/2	16 x 4
50 degrees to March 9.....	66	Buds	70	31	0	0	24	2	15 x 2 1/2
50 degrees to March 16.....	75	Buds	70	31	0	0	24	2	15 x 2 1/2
	Number Days at 50 Degrees When Buds Showed		Age When Buds Showed (Days)	Days From Bud to Bloom	Number of First Lobed Leaf	Age at Time of Lobing (Days)	Average Height (Inches)	Average Length of Inter Node (Cms)	Average Size of Leaf (Cms)
65 degrees to February 3.....	38		70	33	No lobed leaves		17	1	14 x 3
65 degrees to February 10.....	31		70	35	14	60	17	1	14 x 3
65 degrees to February 17.....	32		79	44	15	60	13	1 2	12 x 2
65 degrees to February 24.....	29		83	46	16	60	17	1 2	14 x 2 1/2
65 degrees to March 2.....	34		94	45	18	60	10	4 5	16 x 3
65 degrees to March 9.....	47		114	34	17	60	11	1 2	17 x 3
65 degrees to March 16.....	47		112	25	18	60	8	1 2	17 x 3 1/2
Cold—Check.....	—		70	29	0	0	26	2	12 x 2 1/2
Warm—Check.....	No buds			—	—	16	60	3 5	20 x 4

is also influenced by temperature. In the determination of the first lobed leaf, the leaves were counted starting at the bottom, so that in the table the "Number of First Lobed Leaf" means the number of the leaf up from the base of the plant.

Table III suggests the following conclusions:

1. At 50 degrees F, 52 days were required for bud initiation from the time the seed was planted. Evidently buds initiated when plants were between 45 and 52 days old.

2. More than 1 week at 50 degrees F was necessary for normal bud development after bud initiation. The buds on plants moved to 65 degrees F before the plants were 66 days old were deformed so that the petals were small and the calyx enlarged.

3. At 50 degrees F buds became visible when the plants were 70 days old. Data, not presented, show at this stage the average number of leaves per plant was 18.

4. When plants were grown at 65 degrees F and then the temperature was lowered to 50 degrees F an average of 37 days was required for buds to make their appearance.

5. There were indications that the longer the plants were left at 65 degrees, the longer it took for buds to appear when the temperature was lowered.

6. A temperature of 65 degrees produced lobed leaves. These appeared when the plant was 60 days old, when the plants averaged 15 leaves. At the time lobed leaves appeared, plants were mature enough to initiate buds. Stocks grown at 65 degrees F until the first lobed leaves formed, developed buds in less time than those kept at 50 degrees constantly.

7. Plants grown at 65 degrees had shorter internodes and larger leaves than those grown at 50 degrees. A temperature of 50 degrees favored elongation, while at 65 degrees stocks rosetted, and elongated slowly.

8. After buds had developed on stocks, a temperature of 65 degrees did not produce lobed leaves.

EFFECT OF ADDITIONAL LIGHT WITH ALTERNATING TEMPERATURE

Another experiment was made to show the effects of alternate periods of high and low temperature with additional light at night on the flowering of lavender column stocks. The treatment started January 1, 1936, with plants grown at 65 degrees until the leaves were well lobed. Treat-

TABLE IV—EFFECT OF ADDITIONAL LIGHT WITH ALTERNATING TEMPERATURE

Period of Additional Light	Number Hours Additional Light	Height With 50 Degrees at Night (Inches)	Height With 65 Degrees at Night (Inches)
5 to 7 p.m.	2	28	13
5 to 9 p.m.	4	30	16
5 to 11 p.m.	6	30	18
5 p.m. to 1 a.m.	8	33	21
5 p.m. to 3 a.m.	10	34	18

ment stopped March 24, 1936, when the 50 degrees check was in bloom. Table IV indicates the treatment and the growth response.

One set of these plants was taken from a 65 degree house to a 50 degree house at 4:30 to 5 p. m. and given additional light as indicated in Table IV before being returned to the 65 degree house at 7 a. m. Another set of stocks was taken from a 50 degree house to a 65 degree house at 4:30 to 5 p. m. and given similar periods of light before being returned to the 50 degree house at 7 a. m.

It can be seen that:

1. Additional light had no effect on bud initiation. A definite photoperiodic effect was found with leaf lobing. Even at a minimum temperature of 65 degrees lavender column stocks produced linear instead of lobed leaves when they received more than 15 hours of light during the course of 24 hours.

2. A temperature of 65 degrees at night inhibited plant elongation more than 50 degrees.

3. While Post (2) found that stocks kept at a day temperature of 50 degrees and a night temperature of 60 degrees formed buds, it is evident from the preliminary work that 60 degrees is not low enough to prevent the flowering of young, actively growing stocks. However, 65 degrees is high enough to do this. Observations made during past seasons show that after stocks are four months old, the rate with which buds are formed is much slower than when they are two months old.

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Temperature, Photoperiod, Flowering and Morphology in Cosmos and China Aster

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CONSIDERABLE research (1, 2, 3, 4, 5), has been done on the effect of photoperiod or of temperature or a combination of the two, on the flowering and seed stalk formation in a number of horticultural plants. These studies rarely included data on effect of these variables on morphology. This study was an attempt to measure the effect of both temperature and photoperiod on the general top and root growth as well as on flowering of a typical long day and a typical short day plant. China aster (*Callistephus chinensis*, variety Heart of France), was chosen as the long day plant and cosmos (*Cosmos sulphureus*, variety Klondyke), was chosen as the short day plant.¹

PROCEDURE

The plants were grown in two adjoining greenhouses where the temperatures were manually controlled but electrically recorded. Weekly temperature did not vary more than 2.5 degrees F from the mean. The plant material was grown in compost soil in pots, and both the plants and the soil were tested from time to time with quick tests (6) and gave adequate tests for nitrates, phosphorus and potassium.

The check plants in each house were exposed to natural daylight which varied from 9¼ to 13 hours during the experiments. The treated plants in each temperature were exposed to natural daylength plus 2 foot candles of incandescent lamp illumination from sundown to midnight. This maintained a photoperiod of from 16 to 18 hours.

The seedlings were placed in the plots as soon as they were potted and left for 30 days. At this time half the plants in each plot were moved to another plot where the same photoperiod was maintained, but the temperature was different. They were then left in these plots until harvested or they flowered. Shortly before flower buds could be detected on the plants in the plot where development was most advanced, half the plants in every treatment were harvested on the same day and measured for height and fresh and dry weight of tops and roots. Leaf area was measured by means of the photoelectric device described by Withrow (7). The foliage of the entire harvest was used. When the plants flowered the dates of initial flowering, medium flowering, and last flowering were recorded for each plot.

The plots are designated in such a way that the letter L stands for long photoperiod, the letter S for short photoperiod, the number 68 for 68 degrees F and the number 55 for 55 degrees F. The plants in plot L68 were therefore given long days of 16 to 18 hours duration and a temperature that averaged close to 68 degrees F. The designa-

¹The advice and criticism of Dr. Laurenz Greene and Mr. R B Withrow in carrying out the experiment and in preparation of the manuscript are gratefully acknowledged.

tion L68-L55 signifies that the plants were exposed for the first 30 days (November 13, 1935 to December 13, 1935) to 16 to 18 hour photoperiods at 68 degrees F, and were then transferred to a plot where the photoperiod was still 16 to 18 hours but the temperature was 55 degrees F. The label of each plot thus also gives the treatment of the plants in the plot.

RESULTS OBTAINED ON COSMOS

The temperature of 55 degrees F was found to be too low for good growth of Cosmos but the temperature could not be raised since a temperature around 60 degrees F was known to be the lower threshold of the temperature response in China aster. The plants were slightly chlorotic and developed slowly. About 20 plants from each plot were harvested on December 26. The plants in one of the plots were just beginning to show flower buds. Table I shows the data obtained from the harvest.

In all cases the plants subjected to a long photoperiod were taller than the plants given the same temperature but subjected to a short photoperiod. The difference which was consistent but not large at the time of harvest became greater as time went on, since the plants in the long photoperiod plots continued to elongate while the plants given the short photoperiods flowered and ceased to elongate.

Two distinct growth responses to photoperiod could be noted depending on the temperature treatment. If the plants were exposed to the higher temperature throughout life or during the first 30 days after germination, they responded to short photoperiod and produced greater total dry weight and greater leaf area than the plants in the long photoperiod. Where lower temperature was maintained throughout life or during the first 30 days the reverse took place, and the plants exposed to a long photoperiod had the greatest dry weight and leaf area.

Photoperiod had no appreciable effect on the top root ratio of cosmos. Plants given identical temperature treatments, but different photoperiods, had almost identical top root ratios, even though dry weight, height and leaf area varied widely. This result was similar to that obtained by Withrow and Benedict (9) working with salvia, another non-tuberizing short day plant.

The higher temperature stimulated growth, especially of the top, in cosmos. The plants in the higher temperature plots had a greater height, greater total dry weight, greater leaf area and greater top-root ratio than the plants given the lower temperature. The amount or the effect varied with the length of the exposure. The plants exposed to the higher temperature throughout life were larger than the plants exposed only during the first 30 days and these in turn were larger than those exposed only the last 13 days before harvest. The plants grown in the lower temperature throughout grew the least.

RESULTS OBTAINED WITH CHINA ASTER

Long photoperiod increased top growth in China aster. The plants exposed to the long photoperiod had a greater height, greater leaf area,

TABLE I—COSMOS (20 PLANTS) (SEEDED OCTOBER 28, 1935; POTTED NOVEMBER 11; LIGHTED NOVEMBER 13; CHANGED TO DIFFERENT TEMPERATURE DECEMBER 13; HARVESTED DECEMBER 26)

Plot Number*	Treatment	Average Height (Cm)	Average Leaf Area (Cm ²)	Average Fresh Weight Tops (Grams)	Average Fresh Weight Roots (Grams)	Average Dry Weight Tops (Grams)	Average Dry Weight Roots (Grams)	Average Dry Weight Plants (Grams)	Top Root Ratio (Dry Weight)
L68	Long day 68 degrees F	13.7	26.5	1.33	.37	.135	.029	.164	4.7
S68	Short day 68 degrees F	12.7	35.0	1.75	.50	.195	.042	.237	4.6
L68-L55	Long day 68 degrees F to long day 55 degrees F	10.4	16.4	.74	.25	.094	.027	.121	3.5
S68-S55	Short day 68 degrees F to short day 55 degrees F	8.7	27.2	1.07	.40	.153	.042	.195	3.6
L55-L68	Long day 55 degrees F to long day 68 degrees F	4.2	5.0	.33	.12	.027	.013	.040	2.1
S55-S68	Short day 55 degrees F to short day 68 degrees F	3.1	3.0	.23	.10	.022	.009	.031	2.4
L55	Long day 55 degrees F	3.3	3.0	.21	.11	.023	.015	.038	1.5
S55	Short day 55 degrees F	2.6	1.8	.13	.08	.015	.011	.026	1.4

* L—long photoperiod (16 to 18 hours)
 S—short photoperiod (9½ to 13 hours)
 68—68 degrees F.
 55—55 degrees F.

greater total dry weight and a greater top root ratio than the plants given the same temperature but given a short photoperiod. The amount of root growth within any two comparable plots seems to have been but slightly affected by photoperiod; the differences in total dry weight were largely differences in top development. The wide variation in top-root ratio, of course, reflected this as Table II shows.

High temperatures favored growth, especially of the top, and the longer the exposure the greater the effect. Height, dry weight of tops, leaf area and top-root ratio decrease successively as one goes from plot S68 to S55-S68 to S68-S55 to S55. The same relationship holds for the plants in plots L68, L55-L68, L68-L55 and L55.

THE EFFECT OF DAYLENGTH AND TEMPERATURE ON STEM ANATOMY

At the time of harvest free hand sections of the stems of cosmos and of aster were made at a definite distance above the cotyledons. Sections were made of representative plants and then placed under the low power in a microscope and the outlines of the phloem, xylem and cambial region were drawn using a camera lucida. The outlines were then traced, inked and shaded so that the different tissues stood out clearly.

In China aster, stem diameter and vascular differentiation was greater in the higher temperature irrespective of photoperiod. The plants grown in the short photoperiod had a greater stem diameter than those grown in a long photoperiod. A striking correlation was shown between top-root ratio and the relative amounts of phloem and xylem. In short photoperiods the amount of phloem relative to the amount of xylem was large. These same plants also had relatively large roots as was shown by a low top-root ratio.

Like aster, the stems of the cosmos plants in the higher temperature were slightly greater in diameter than those in the lower temperature and vascular development was greater. Photoperiod had little effect on stem diameter and apparently no effect on the relative amounts of phloem and xylem. Table I shows that photoperiod had also no effect on top-root ratio.

It is conceivable that the short photoperiod retards N assimilation in the top of long day plants, such as China aster, and since photosynthesis continues to supply carbohydrates, which are not used up as freely as normally in the formation of new top tissue, the phloem and the roots are relatively better supplied with carbohydrates than they would be if the plant were exposed to a long photoperiod and the top were assimilating a larger proportion of the carbohydrates in growth. Being better supplied with carbohydrates, both phloem and roots grow more vigorously and form a larger proportion of the plant.

FLOWERING DATA ON COSMOS

Since the cosmos has indeterminate flowering it was arbitrarily decided that only the number of flowers opening 30 days after the time of first flowering would be included in the data. Flower diameter was not measured since the variation was known to be small. The data are given in Table III.

TABLE II—ASTER (25 PLANTS) (SEEDED (OCTOBER 28, 1935; POTTED NOVEMBER 11, LIGHTED NOVEMBER 13; CHANGED TO DIFFERENT TEMPERATURE DECEMBER 13; HARVESTED JANUARY 28, 1936)

Plot Number*	Treatment	Average Height (Cm)	Average Leaf Area (Cm ²)	Average Fresh Weight Tops (Grams)	Average Fresh Weight Roots (Grams)	Average Dry Weight Tops (Grams)	Average Dry Weight Roots (Grams)	Average Total Dry Weight (Grams)	Top Root Ratio (Dry Weight)
L68	Long day 68 degrees F	9.60	24.7	10.70	1.72	1.32	.19	1.51	7.0
S68	Short day 68 degrees F	1.95	15.8	5.32	1.46	.65	.14	.79	4.6
L55-L68	Long day 55 degrees F to long day 68 degrees F	7.9	16.3	9.13	1.16	.84	.12	.96	7.0
S55-S68	Short day 55 degrees F to short day 68 degrees F	1.89	12.1	4.25	1.72	.48	.13	.61	3.7
L68-L55	Long day 68 degrees F to long day 55 degrees F	5.64	14.6	8.45	4.12	.89	.26	1.15	3.4
S68-S55	Short day 68 degrees F to short day 55 degrees F	2.24	8.1	3.44	2.88	.47	.23	.70	2.1
L55	Long day 55 degrees F	3.63	7.2	7.50	1.96	.51	.12	.63	4.3
S55	Short day 55 degrees F	1.43	5.0	2.30	1.80	.29	.12	.41	2.4

* L—long photoperiod (18 to 18 hours).

S—short photoperiod (9½ to 13 hours)

68 to 68 degrees F

55 to 55 degrees F

TABLE III—COSMOS DATA AT FLOWERING TIME (SEEDED OCTOBER 28, 1935; POTTED NOVEMBER 11; LIGHTED NOVEMBER 13; CHANGED TO DIFFERENT TEMPERATURE DECEMBER 13)

Plot Designation	Treatment	Date of First Flower	Average Number of Flowers in 30 Days	Average Stem Length (Cm)	Number of Plants
L68	Long day 68 degrees F	_____	—	—	16
L55-L68	Long day 50 degrees F to long day 68 degrees F	_____	—	—	18
S68	Short day 68 degrees F	January 6	5.2	14.8	15
S55-S68	Short day 50 degrees F to short day 68 degrees F	February 15	12.6	14.0	12
L55	Long day 50 degrees F	_____	—	—	15
	long day 50 degrees F	_____	—	—	16
S55	Short day 50 degrees F	_____	—	—	15
S68-S55	Short day 68 degrees F to short day 50 degrees F	February 1	2.3	3.6	10

Cosmos plants exposed to a 16 to 18 hour photoperiod, failed to flower in any temperatures used in the experiment. No temperature used overcame the inhibiting action of the long photoperiod. The plants exposed to a short photoperiod and a cool temperature throughout life also failed to flower. These plants grew very slowly and it is problematical whether the low temperature inhibited the onset of flowering or merely slowed down growth so much that flower buds failed to develop within the time of the experiment.

The difference in time of flowering because of temperature was a difference in the rate of flower bud development and not one of flower bud formation. The buds on all the plants that ever flowered were visible at approximately the same date. The plants in the higher temperature developed the flower buds rapidly while the plants in the lower temperature developed them slowly.

In the warm house the amount of flowering in cosmos seemed to vary with the amount of sunny weather. The plants in plot S68 flowered quite profusely only near the end of the 30 day period when data were taken. A period of sunny weather began about that time. The plants moved from the cool temperature (plot S55-S68) came into flowering during this sunny weather and bore more blossoms in 30 days than the plants in plot S68.

DATA ON ASTER FLOWERING TIME

The flower data on aster are given in Table IV. The flowering date of a plot was considered as the time when half the plants showed at least one open flower. This created a standard independent of the irregular flowering characteristic of some temperature treatments. Note was made of the time when the first plant in the plot flowered, when half the plants in the plot were in flower, and when the last plant in the plot came into flower. The data showed that approximately the same period of time elapsed from the date the first plant flowered to the date when half were in flower, as from the latter date to the time when all were in flower.

TABLE IV—ASTER DATA AT FLOWERING TIME (SEEDLINGS OCTOBER 28, 1935; POTTED NOVEMBER 11; LIGHTED NOVEMBER 13;
CHANGED TO DIFFERENT TEMPERATURE DECEMBER 13)

Treatment	Plot Designation	Time of Median Flowering	Length of Time From First to Last Flower (Days)	Height (Cm)	Number of Flower	Stem Length (Cm)	Flower Diameter (Cm)	Number of Plants
Long day 68 degrees F	L68	March 15	20	32.8	4.7	18.4	6.3	19
Long day 55 degrees F to long day 68 degrees F	L55-L68	March 20	18	34.5	4.1	20.7	5.5	22
Short day 68 degrees F	S68	March 20	31	12.0	6.2	5.6	4.7	20
Short day 55 degrees F to short day 68 degrees F	S55-S68	April 12	32	14.1	6.1	4.7	5.8	23
Long day 55 degrees F	L55	March 31	14	28.3	4.4	15.4	8.2	25
Long day 68 degrees F to long day 55 degrees F	L68-L55	March 23	11	28.3	5.5	14.0	7.6	20
Short day 55 degrees F	S55	—	—	—	—	—	—	24
Short day 68 degrees F to short day 55 degrees F	S68-S55	—	—	—	—	—	—	28
Long day 68 degrees F to short day 68 degrees F	L68-S68	February 20	10	7.6	4.6	2.3	4.6	8
Long day 55 degrees F to short day 55 degrees F	L55-S55	March 25	14	10.5	3.9	7.8	6.3	8

*Were not in flower on April 26, 1936 when the experiment ended

In general, the temperature of the aster plant during the first 30 days of treatment had little effect on the final shape and flowering habit of the plant, but had some effect on time of flowering. At the time the plants were half grown the differences were marked but as the plants approached flowering the differences seemed to even out. Higher temperatures early in the life of the plant had a slight hastening effect on flowering, while the cool temperatures early in life had a retarding effect on flowering.

Richman (8) found that photoperiod had its greatest effect during the period from 15 to 45 days after the seeds of China aster germinated. A repetition of his treatments gave substantially the same results. The last two treatments on Table IV give this data.

When China aster plants grew throughout life in a high temperature and long days, or were subjected to these conditions later in life, the plants flowered early and produced long stemmed flowers with moderate diameter. The flowering was regular and the first flowers to open were still in good shape before the last ones opened. The flowers were of fair quality but the petals were not as quilled as is characteristic of the variety.

Under conditions of short days and high temperatures during all or the latter part of the plant's life, the plants flowered rather profusely, but had small flowers on short stems. Flowering was very irregular and the first flowers in the plot to open were completely faded before the last flowers opened. The flowers were of poor quality, the petals being strap shaped and almost reflexed. Several plants of this series were given a photoperiod of eight hours to see if this would overcome the stimulation of the higher temperatures. The plants were somewhat small but flowered at the same time as the others of the plot.

Low temperatures with long days given throughout life or during the latter half of life produced vigorous flowering in aster. The plants flowered 2 weeks later than the plants in the higher temperatures. They had just as many flowers as the plants in the higher temperature, but the stem length was shorter. Flower diameter, on the other hand, was considerably greater than that of the plants in the higher temperatures. The flowers were of fine quality.

The plants given the lower temperature and short photoperiod throughout life or during the latter part of life remained in the vegetative state and showed no sign of flowering throughout the experiment. Neither 30 or 60 days of the higher temperature early in life were sufficient to overcome the inhibiting effect on flowering of low temperature and a short photoperiod.

CONCLUSIONS

From these data it would appear that a high temperature and/or a long photoperiod favor top growth on both a typical long day and a typical short day plant. It is also evident that while China aster will flower at high temperatures even in the shortest daylengths of the year the stems are very short and a long photoperiod is necessary for the development of the normal habit of growth.

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Effect of Excess Fertilizers on Roses, Snapdragons, and Chrysanthemums

By KENNETH POST and ROBERT S. BELL, *Cornell University, Ithaca, N. Y.*

THIS investigation was undertaken because of the great number of injured plants sent to the college for diagnosis, which were apparently growing in very rich soil. The first work was done with Joanna Hill roses growing in the greenhouse bench and receiving the usual commercial rose culture. Each plot contained 20 plants. The experiment was run from November 16 to February 15. The symptoms of each injury will be reviewed briefly.

Ammonium sulphate applied at the rate of 5 pounds to 100 square feet of bench area every 2 weeks caused the leaves to become light yellow with dark green veins. The new leaves were nearly white with a pink blush. The pH dropped from 6 to 4.6. Whether the injury was due to the toxic effect of the low pH or to toxic compounds soluble at this pH was not discovered. When the soil was treated with lime so that the reaction became pH 5.4, the leaves developed normal color again.

Nitrate of soda applied at the rate of 5 pounds to 100 square feet every 2 weeks caused severe defoliation. The edges of the leaves turned brown, and yellow streaks developed between the veins. The leaves which developed after the injury was noted on the old leaves were soft in texture and light green in color. They were large, and wider in proportion to length than normal.

Muriate of potash used at the rate of 3 pounds to 100 square feet of bench area caused a reddish brown color to develop along the margins of the old leaves. The new leaves were light greenish yellow in color.

Superphosphate applied at the rate of 15 pounds to 100 square feet of bench area at 2 week intervals hardened the growth decidedly, but no leaf injury appeared during the experiment.

SNAPDRAGONS

The snapdragon variety Coats Yellow was used in this experiment. The plants were started from cuttings January 21, 1936 and were grown in 4-inch pots. Ten plants were used in each treatment, five of them being grown in washed sand, and five in composted soil. They were fertilized with a full nutrient solution weekly to prevent a deficiency of any element from complicating the excess symptoms. This treatment began March 9, 1936.

The following salts were added at weekly intervals at the rate of 1 gram per pot: Calcium carbonate, ammonium sulphate, calcium nitrate, sodium nitrate, sodium acid phosphate, and potassium chloride. The lime was used in water suspension and the others in solution. About 1 month was required for symptoms of excesses to appear in the soil tests. The plants in sand were so severely injured by the more soluble salts, such as sodium nitrate and ammonium sulfate, that many died after the first application.

GENERAL SYMPTOMS

The plants treated with calcium carbonate were light green in color and showed no severely injured areas. All other salts caused light yellow chlorotic areas to appear between the veins of the younger leaves. When the treatment was stopped and the soil leached, the new leaves which developed were green. The older leaves became green also. Ten days after making another application of salts, however, the chlorotic areas reappeared in the newly formed leaves.

Plants treated with excess nitrate of soda had larger leaves, and as the nitrate accumulated, dead areas appeared in these leaves.

Ammonium sulfate caused the leaves and soft stem tips to wilt and droop badly. The plants gradually dried and died.

Excess phosphate killed the terminal growth of the snapdragons. The younger leaves died and the plants were dwarfed. The flowers were small, malformed, and nearly white rather than the normal yellow color.

Potash injury caused the petioles of the leaves to wither and the adjacent leaf bases became brown, allowing the leaves to hang down along the stem.

CHRYSANTHEMUMS

The chrysanthemum varieties H. E. Kidder and Detroit News were grown in 5-inch pots of the regular potting soil. Ammonium sulfate, potassium chloride, and sodium nitrate were applied both singly and in combinations. Twenty-five grams of a salt were dissolved in 1 liter of water and 200 cc applied to each pot every 2 weeks. The superphosphate, lime, and 5-10-5 were added at the rate of 1 gram per pot. Ten plants of each variety were used for every treatment. The treatments were not started until August 12 when the chrysanthemums were about 18 inches high.

Ammonium sulfate in excess caused a definite wilting on sunny days. This same symptom was evident with the snapdragons. It was very easy to tell every plant treated with ammonium sulfate because of this flagging on bright days.

The plants treated with superphosphate and lime were not particularly different from the checks. The leaves were lighter green than normally. Potassium chloride did not give definite injury symptoms except a slight stunting. The 5-10-5 gave excellent growth and dark green leaf color.

Sodium nitrate caused chlorotic areas to appear on the younger leaves. The growth of the tip was reduced and produced a rosetting of the leaves.

When both potassium chloride and sodium nitrate were added the salt concentration was so high that the plants became very chlorotic and died.

CONCLUSION

Ammonium sulfate in excess caused severe wilting of snapdragons and chrysanthemums. Excess soluble salts caused definite leaf symptoms on roses. Excesses on other plants generally caused chlorotic areas to appear in the young leaves, accompanied by a retardation of growth.

A Preliminary Study of the Effect of an Alfalfa Meal Mulch on Carbondioxide Liberated and the Growth of Pompom Chrysanthemums

By ROBERT S. BELL, *Cornell University, Ithaca, N. Y.*

A STUDY of several mulching materials showed that they liberated considerable carbon dioxide when decomposing. Certain investigators have shown that this CO_2 can act as an aerial fertilizer when conditions of light, temperature, and moisture are correct.

Lundegardh (3) has reported that CO_2 from decomposing manure mulches increased the yield of field crops, notably beets. He pointed out, however, that when the CO_2 evolved passed a certain upper limit, the treatment became toxic. Appleman (1) found a decided toxic effect on potatoes from the use of large quantities of organic matter. Gerlach (2) found that the CO_2 from decomposing manure had no effect at all on the yield of his crop plants. Bacher (6) made experiments which indicated that ammonia liberated from manure was more stimulating to plant growth than the CO_2 .

Ground alfalfa meal was selected as a mulch for the experiments reported here, because it contains more than enough nitrogen to bring about decomposition of the organic matter, according to Waksman and Starkey (5). Thus the decomposing alfalfa should supply some nitrogen as well as CO_2 and be doubly useful.

The data reported in this paper are taken from plots (3 feet by 17 feet) on the opposite ends of a greenhouse bench, 34 feet of other plants growing between the test plots. The soil throughout the bench was from the same compost pile, and the same number of uniform plants of Elora, Pink Popcorn, Yellow Fellow, Usona, Red Wilcox, and Copper City varieties of pompom chrysanthemums were planted in each plot.

The alfalfa meal was applied at the rate of 10 pounds to 100 square

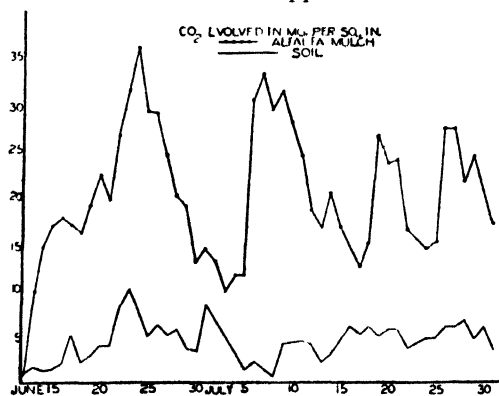


FIG. 1. Carbon dioxide evolved.

feet of surface every 8 to 14 days, depending upon how rapidly the CO_2 output dropped. The CO_2 was determined from an area of 17.6 square inches. A small, shallow crystallizing dish was raised from the soil by a piece of wire gauze. This contained .4 normal KOH. A large crystallizing dish was placed over this and pushed into the soil a short distance. Every 24 hours the KOH

was titrated with .1 normal HCl and the amount of CO₂ computed. Two determinations were made for each plot. Blanks were run by placing the above apparatus on a flat plate, which gave a correction for the original amounts of CO₂ present in the system. The corrected results were averaged and reduced to milligrams of CO₂ per square inch of surface soil area. They are shown in Fig. 1.

The CO₂ evolution increased rapidly with applications of alfalfa, but in a few days dropped, showing a very rapid rate of decomposition. The pH of the soils in both plots remained around 6.5. No significant differences appeared. The nitrates as determined by the phenol disulphonic acid test showed an increase from 4 ppm to 12 ppm under the alfalfa treatment, which was maintained until September 15, after which time no nitrogen determinations were made or more alfalfa added. However, all plots were fertilized with ammonium sulfate every 2 weeks at the rate of 1 pound to 100 square feet. The nitrate concentration of the check plot ran between 4 and 5 ppm after this date.

By the last of August the check plot appeared slightly better than the treated one. When the flowers were cut in November the number of stems were counted and the weight in grams noted. The data appear in Table I.

TABLE I—YIELD OF POMPOM CHRYSANTHEMUMS TREATED WITH ALFALFA MULCH

Varieties	Eight Applications of Alfalfa		Two Applications of Alfalfa		Check	
	Number of Stems per Plot	Average Weight per Stem (Grams)	Number of Stems per Plot	Average Weight per Stem (Grams)	Number of Stems per Plot	Average Weight per Stem (Grams)
Elora	156	31.0	129	36.9	168	35.6
Pink Popcorn	139	27.7	115	34.4	123	35.2
Yellow Fellow	95	41.4	90	50.2	100	57.3
Usona	78	42.1	99	36.9	98	41.1
Red Wilcox	106	35.8	78	45.8	38	62.3
Copper City	102	25.7	112	32.1	126	33.8
Average stem weight	—	34.1	—	39.4	—	44.2

The average weight of 653 stems of flowers in the check plot was 4.2 grams, while the average weight of 676 of those treated with ground alfalfa meal was only 34.1 grams. The number of flowers cut from each plot was nearly the same, but the weights varied greatly. The third plot received two applications of alfalfa before the middle of July, and none after that, but the weight of the crop averaged only 39.4 grams for 623 stems of flowers.

It is evident in this experiment that alfalfa, as used, had an inhibitory effect upon the growth of pompom chrysanthemums. Lack of nitrogen cannot in itself account for the lower weight of the treated plants. There is a possibility that the decay of such readily decomposable organic matter produced toxic substances which inhibited the growth of the plants.

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Influence on Grass Growth of Various Proportions of Peat in Lawn Soils¹

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MOST directions for the making of a new lawn recommend the incorporation of considerable organic matter into the soil. One material frequently recommended, especially in recent years, is peat of various types. The reasons usually given for the addition of peat are that it puts the soil into a better physical condition and also increases the water holding capacity of the soil; thus ensuring the grass a more stable moisture supply. However, Laurie (1), McCool (2, 3), and Longley (4) have shown that in some cases with other plants peat may actually be used to replace barnyard manure in supplying fertility elements. The following experiment was conducted to determine the effects of incorporating peat into lawn soil on the germination of the seed and on the subsequent growth of the lawn.

Plots 4 x 8 feet (1931) and 8 x 8 feet (1932) were set up in duplicate on Hempstead loam soil. Peat, 1, 2, and 4 inches, was applied before seeding and spaded under in such a way as to become well mixed with the soil.

In 1931 peats from three widely different sources and differing greatly in properties, were used but in 1932 only two of these. These peats were selected and provided by the Division of Soils of the University of Minnesota, in cooperation with which this experiment and was planned and carried out, to represent the extreme range in character that will ordinarily be encountered in this country. In the following discussion they are designated as A, B, and C peats.

In 1931 several seedings were made; in the first seeding (May 22) the peat was wetted before application but not in the other seedings. In 1932 a single seeding was made. The grass seed mixture used was composed as follows: Kentucky blue grass 60 per cent; red top 20 per cent; perennial rye grass 10 per cent; and white clover 10 per cent. The seed was sown at the rate of 1 pound of this mixture to 250 square feet.

Observations were made through 1935, the notes being taken by one person to ensure uniform judgment. The grass was rated on the basis of thickness and luxuriousness of growth and on the scale of 1. Good+; 2. Good; 3. Good-; 4. Fair+; 5. Fair; 6. Fair-; 7. Poor+; 8. Poor; 9. Poor-. In Tables I and II are summarized the results for the seedings of May 22 and July 22, 1931, and August 25, 1932. The results for the other seedings in 1931 are omitted as not differing sufficiently from those of July 22 to warrant inclusion.

NOTES ON PLOTS SOWN IN 1931

First Seeding (May 22):—With the first seeding the check plot gave the poorest germination with the exception of the 4-inch peat B plot. By the end of 1932, the check plot, the 1-inch, and the 2-inch peat plots, all are marked Good except the peat B 2-inch lot which is

TABLE I—NOTES ON LAWN PLOTS RECEIVING VARIOUS AMOUNTS OF PEAT BEFORE SEEDING. SOWN IN 1931

Material	1931 Notes	1932 Notes		1933 Notes		1934 Notes
	September 16	June 13	September 23	May 17	September 15	September 19
<i>Seeded May 22</i>						
Check	9	5	2	2	3	2
1-inch A peat	6	8	2	1	1	3
1-inch B peat	5	4-5	2	2	2	3
1-inch C peat	4	7	2	1	1	1-2
2-inch A peat . . .	4 5	7	2	1	1	1
2-inch B peat . . .	6 7	5	4	1*	2	1
2-inch C peat	4	8	2	2	1	1
4-inch A peat	4	8	4*	2*	1*	1*
4-inch B peat	9	9	5*	3*	2 3	2
4-inch C peat	4	8	6*	2*	1*	1*
<i>Seeded July 22</i>						
Check	5	5	2-3	2	2	2
1-inch A peat . . .	9	5-6	3	1	1 2	1
1-inch B peat . . .	5	5	2 3	2	1-2	1-2
1-inch C peat . . .	9	8	2-3	2	3	3
2-inch A peat . . .	9	5	4	8	1†	1†
2-inch B peat . . .	6	6	1-2	1	1	1
2-inch C peat	9	8	1-2	1	1	1
4-inch A peat	9	5	2*	6-7*	3*	3†
4-inch B peat	6	7	4*	1*	1*	1-2*
4-inch C peat	9	7	1*	5*	1*	2*

*Spongy turf

†Moderately spongy turf.

‡Very spongy turf.

Fair+. The 4-inch lots are only mediocre and the turf in this mixture is spongy and soft. By the end of 1933 all plots were Fair— or better, but the growth in all the peat plots was at least slightly better in every case than the check plots. Those receiving 4 inches of peat showed a good stand and growth but the turf was soft and spongy. By the end of 1934 about the same condition obtained tho there was a slight shift in the ranking of the plots, with the 2-inch lots better than either the 1-inch or 4-inch lots. Here the 4-inch lots showed very soft and spongy turf. Consistent differences between the kinds of peat are not apparent.

Second Seeding:—In the seeding July 22, the germination was poorer in all of the peat plots as compared to the check except in the 1-inch B peat plot. In fact, all the peat plots had a very poor germination except the B peat which was somewhat better than the others in all cases.

By the end of 1932, all the plots had improved in stand to at least

TABLE II—NOTES ON LAWN PLOTS RECEIVING VARIOUS AMOUNTS OF PEAT BEFORE SEEDING, SOWN AUGUST 25, 1932

Material	1932 Notes	1933 Notes		1934 Notes	1935 Notes	
	September 26	May 17	September 18	September 19	July 2	August 20
North check . . .	1	2	2	2	2	2
1-inch A peat . . .	2	6	1*	1*	1	2
1-inch B peat . . .	2	3	3	1	1	2
2-inch A peat . . .	2	7	1	1	1	2
2-inch B peat . . .	2	4	1	1†	1	2
South check	1	3	3	2	2	2

*Slightly better than the 1-inch B peat.

†Slightly better than the 2-inch A peat

Fair+ as in the 2-inch A and the 4-inch B peat plots. All the others were good— or better, but all 4-inch plots were very soft and spongy.

By the end of 1933, all peat plots showed a heavier growth and better turf than the check except the 4-inch A peat and 1-inch C peat which was slightly poorer; and this rating held good thru 1934. Also by the end of 1934 the 4-inch plots all showed a very soft spongy turf, too soft for a good lawn. This was also true to a lesser extent of the 2-inch A plot.

For the 1931 seedlings as a whole the 2-inch peat plots showed consistently better growth than either the 1-inch or the 4-inch plots.

NOTES ON PLOTS SOWN IN 1932

Table II gives the data for the plots sown in 1932. Only one seeding was made, namely, on August 25. Only two sorts of peat were used, namely, the A and B; and only the 1-inch and 2-inch applications. The notes taken on September 26, 1932, indicate that the check plots had a somewhat better stand than those with peat. By the end of 1933 the stand in the peat plots was better in all cases than in the check, and the growth was likewise better, except in the case of the 1-inch B peat. This was especially true of the 2-inch A plots. The 1934 notes show about the same relations. The check has a good stand and growth; the peat plots still better with the notes indicating that the 1-inch A plots is a trifle better than the 1-inch B plot, while as to depth of peat application, the following is true: the 1-inch application seems a trifle better in the case of the A peat, but the 2-inch is better with the B peat. The notes for July 2, 1935, indicate that the plots which had received peat were slightly better than the checks. No appreciable difference was evident between the 1-inch and 2-inch applications, and none between the two sorts of peat. At the time the notes were taken in August, 1935, no appreciable difference was noted between any of the plots.

DISCUSSION

Depression of Germination:—The depression of germination in the peat plots which showed up in all the seedlings except the first, is

probably due to the fact that the peat was very dry when applied except in the case of this first seeding, in which case the peat was wetted thoroly before applying. All the plots received some artificial watering but hardly as much as would be given to the ordinary home lawn seeding. It was difficult to get the peat well wetted by sprinkling. As a result it probably absorbed moisture from the soil, thus keeping it to some extent from the seed, and thereby lowering germination. As is indicated by the better germination in the peat plots with the first seeding, where the peat was wetted, this effect could likely be avoided if the peat were thoroughly wetted before applying or else if the lawn plots were thoroughly soaked some days before seeding to enable the peat to absorb all the moisture possible before the seed was sown. In any case, the effect of this depression on germination is usually soon overcome by the greater growth and stooling of the grass plants.

Increase of Growth in the Peat Plots:—By the second and third season there is a noticeable increase in growth in the plots on which peat is applied as compared to the check plots, regardless of the amount. However, after the fourth season, this difference was not so apparent, particularly in the 1932 seedings. In this series, by 1936 no apparent difference was in evidence between the plots, though it had been evident in previous years.

Softness of Turf in the 4-inch Application:—A 4-inch application of peat is definitely too great to apply to a lawn unless possibly it were spaded and mixed to a depth of at least 1 foot or more. In every case the 4-inch plots were soft and spongy. An application of 2 inches of peat was the best and might be slightly increased without producing a soft lawn. There is no consistent difference between the peats used in the experiments.

SUMMARY

The application of peat to a lawn before seeding depresses the germination of the grass seed unless it is well moistened before application, but later results in a more luxuriant growth. A layer of approximately 2 inches of peat regardless of type was the best for lawn purposes. Heavier applications produce a soft, spongy lawn surface. No record was kept of the influence of the peat on soil moisture or on soil fertility, except as indicated by the growth of the grass.

¹Journal Series Paper No. 1475 of the Minnesota Agricultural Experiment Station.

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A Fertilization Study on Coniferous Evergreens in the Nursery

By P. C. MARTIN and F. E. GARDNER, *U. S. Department of Agriculture, Beltsville, Md.*

ALTHOUGH a great many studies have been made on the nutrient requirements of fruit trees, relatively little evidence, based on adequately planned and carefully executed experiments, is available in the case of coniferous evergreens. The work of McIntyre and White (1, 2) with coniferous forest tree seedlings, presents much helpful information, especially for the forest tree nurseryman.

In view of the lack of information concerning the fertilization of ornamental conifers, and the fact that most nurserymen are prejudiced against the use of mineral fertilizers for evergreens, the present experiments were undertaken. It was hoped to determine for some of the commonly grown evergreens whether, on a fairly fertile nursery soil, phosphorus and potassium, as well as nitrogen, might be expected to increase growth; which of the several commonly used nitrogen carriers could be used to best advantage, and in what amounts; and finally, if mineral fertilizers can satisfactorily be substituted for cow manure, a prized fertilizing material but one generally difficult to secure.

MATERIALS AND METHODS

Two species of evergreens were used, *Thuja occidentalis pyramidalis* (American pyramidal arborvitae), and *Juniperus communis hibernica* (Irish Juniper). The plants of both species had been propagated by cuttings, grown in the transplanting beds for 2 years, and selected

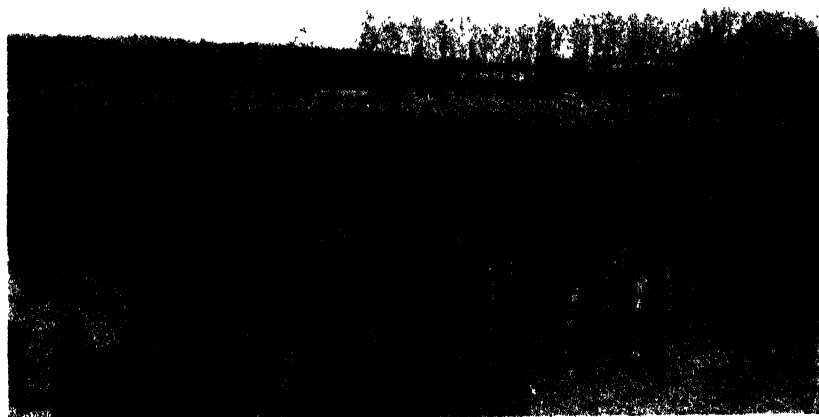


FIG. 1. Irish Juniper plots used in fertilizer study.

for the experiments from a large number on the basis of uniformity. These plants thus represented clonal selections and eliminated to a large extent the variability usually encountered in seedling material. A planting of 1,000 Norway Spruce seedlings, intended for inclusion in this study, was abandoned after 2 years of growth because of such seedling variability.

The plants were set in plot formation in the spring of 1933 and grown two seasons under clean cultivation without any fertilizer treatment. Early in the second growing season (1934) the plants, although exhibiting general uniformity, were pruned in an effort to further reduce slight size differences. The second growing season allowed recovery from such pruning before the fertilizer treatments were started.

Each plot consisted of 20 trees spaced 14 inches apart in four rows which were $3\frac{1}{2}$ feet apart. Five feet existed between plots. Ridges approximately 7 inches high were maintained between plots to prevent surface leaching from one plot to another. Forty plots were made of each of the two plant species. This permitted 10 fertilizer treatments, each replicated three times, the four plots per treatment being scattered systematically.

The soil was a silty clay loam of fair fertility. A winter rye crop and a summer crop of soybeans had been turned under previous to the experiment. The particular area of the tract for the plots was selected because of the uniformity exhibited by these cover crops.

The fertilizers used were of the usual commercial grades. The proportions were carefully weighed out and thoroughly mixed, without filler, before application. The fertilizers were applied in an 8-inch band, 4 inches away from the plants on two sides. The various fertilizer treatments are listed in the tables. The check received no fertilizer; N_1 , N_2 , and N_3 , refer to 200, 400 and 600 pounds per acre of nitrate of soda, respectively, or where so stated, an equivalent amount of nitrogen in the form of urea or sulfate of ammonia; phosphorus and potassium were used uniformly at the rate of 800 pounds of superphosphate and 400 pounds of muriate of potash per acre. The cow manure, free of bedding or other foreign material, was used at the rate of 10 tons per acre. The above amounts were applied twice yearly, one application as plant growth started, and the other about August 1.

The growth of the plants was recorded by circumference and height measurements, and, in order to give proper weight to both measurements, the data were calculated on a cubic inch volume basis. Circumference measurements were made with a graduated, hard-finished cardboard which was drawn snugly around the plants by means of a heavy rubber band attached to one end and pulled to the same degree of tension. Height measurements were made by measuring down to the top of each plant from a horizontal wooden bar which was supported at a known height by uprights, and which extended over an entire plot row. This minimized the error in height measurement due to changes in ground level about individual trees.

In determining the significance of the results, the data were treated by analysis of co-variance. A positive correlation exists (within treat-



FIG. 2. Methods of measuring circumference and height of plants.

ments) between size of tree before and size after treatment, amounting to +.442 for arborvitae and +.465 for Juniper. In view of this influence of size before treatment on final size, and because the size before treatment varies appreciably (Tables II and III), it was necessary to correct the final sizes for true comparisons. To this end, the re-

gression of Y (final size) on X (initial size) was calculated and found to be 5.179 cubic inches for arborvitae and 7.232 cubic inches for Juniper. These regression values multiplied by the deviation of the 80 trees in a treatment from the average initial size of the 800 trees in all treatments, constitute the corrections applicable to the final sizes.

In calculating how much of the total variance was due to treatment and how much due to error, the regression influence was first removed by the formula $B_{yx}^2 X S_x^2 - 2B_{yx} X S_{xy} + S_y^2$, where B_{yx} is the regression value, S_x^2 and S_y^2 are the variances of initial and final tree sizes, respectively, and S_{xy} is the corresponding co-variance. Inasmuch as the variance due to treatment was 7.5 times that due to error in the case of arborvitae, and 13 times in the case of the Juniper, the odds greatly exceed 99 to 1 that significance exists among the differences due to treatment. From Snedecor's F table (4), and the calculated error of the mean difference, it was found that any differences as large as 23.37 cubic inches between treatments of arborvitae, and 14.92 cubic inches between treatments of Juniper are significant at odds of at least 99 to 1.

DISCUSSION OF RESULTS

Table I, showing the soil reaction, as determined by the quinhydrone method on the surface 6 inches of soil, indicates a slight decrease in acidity from the check treatment due to the application of nitrate of

TABLE I—EFFECT OF FERTILIZER APPLICATIONS ON SOIL REACTION

Fertilizer Treatment	Arborvitae Plots		Juniper Plots	
	pH Range of the 4 Plots	Average pH of the 4 Plots	pH Range of the 4 Plots	Average pH of the 4 Plots
Check (no fertilizer) ..	5.5-6.0	5.7	5.7-6.2	6.0
N, PK	5.2-5.2	5.2	5.4-5.7	5.5
N, PK	5.1-5.8	5.5	5.5-5.9	5.6
N, PK	5.3-6.1	5.6	5.9-6.0	5.9
N, P	5.3-6.2	5.7	5.8-6.1	6.1
N, K	5.5-6.1	5.9	5.9-6.4	6.1
N	5.8-6.5	6.2	6.0-6.8	6.4
N, PK (Urea) ..	4.6-5.1	4.9	4.8-5.4	5.1
N, PK (ammonium sulfate) ..	4.4-4.7	4.5	4.5-4.7	4.6
10 tons manure ..	5.9-6.4	6.1	6.0-6.3	6.1

soda alone, and a tendency for urea and sulfate of ammonia to induce a more acid condition. The lack of correlation between final acidity of the plots and the amount of growth as shown in Tables II and III suggest that these evergreens are at least moderately tolerant of variations in acidity and that soil reaction has not been an important factor in the growth differences obtained. This is supported by the work of Odland, *et al.* (3) with these same species.

In considering the effects of the various fertilizer treatments on arborvitae (Table II), a comparison of the check with the N₂ treat-

TABLE II—EFFECT OF VARIOUS FERTILIZER APPLICATIONS ON GROWTH OF ARBORVITAE

Fertilizer Treatment	Average Size of 80 Plants Before Treatment (Cubic Inches)	Size After Two Years Treatment (Cubic Inches)	Correction Due to Regression*	Corrected Final Size† (Cubic Inches)
Check (no fertilizer) . . .	90.06	774.79	+33.30	808.09
N ₁ PK	97.33	915.75	-4.35	911.40
N ₂ PK	93.44	842.46	+15.80	858.26
N ₃ PK	93.28	815.71	+16.62	832.33
N ₂ P	100.90	772.09	-22.84	749.25
N ₂ K	96.82	779.18	-1.71	777.47
N ₂	94.59	721.91	+9.84	731.75
N ₂ PK (Urea)	100.08	864.66	-18.59	846.07
N ₂ PK (ammonium sul- fate)	99.52	853.64	-15.69	837.95
10 tons manure	98.90	890.59	-12.48	878.11
Average	96.49			

*Correction of final size for effect of size before treatments.

†At odds of 99 to 1, a difference of 23.34 cubic inches, or greater, becomes significant

ment shows this amount of nitrate of soda (400 pounds per acre) to be too heavy an application. Two hundred pounds is apparently as much as should be applied to plants of this size. This is supported by the progressive decrease in size among the N₁ PK, N₂ PK and N₃ PK treatments.

Potassium has given a substantial increase in growth (N₂ compared with N₂ K) and especially when used with phosphorus (N₂ P compared with N₂ PK). Phosphorus, however, has shown significant benefit only when accompanied by potassium, as indicated by comparison of the N₂, N₂ P and N₂ PK treatments.

As for the three nitrogen carriers used, sodium nitrate, ammonium sulphate and urea, the results do not indicate any significant advantage of one over another. It is evident, however, that an inorganic carrier such as nitrate of soda, when used in the proper amount and with phosphorus and potassium (N₁ PK treatment) may be advantageously substituted for manure.

Applications of the same fertilizers on Irish Juniper (Table III) produced somewhat different responses, indicating a differential behavior of the two species. The N₂ amount of sodium nitrate alone resulted in a significant increase in growth over the unfertilized check. While Irish Juniper is apparently more tolerant of heavy applications of nitrate of soda than is arborvitae, yet it is apparent from the comparison of the N₁ PK, N₂ PK and N₃ PK treatments that 400 pounds per acre was not as beneficial as 200 pounds.

Significant benefits were obtained from the use of potassium, the N₂ K treatment being better than N₂ alone. With this species, unlike the arborvitae, no benefit was derived from the application of phosphorus; in fact, a detrimental response is indicated in the comparison of N₂ P with N₂. Even if the large regression correction applicable to the N₂ P treatment were not applied, the conclusion seems inescapable that, under our conditions, there was no benefit of phos-

TABLE III—EFFECT OF VARIOUS FERTILIZER APPLICATIONS ON GROWTH OF IRISH JUNIPER

Fertilizer Treatment	Average Size of 80 Plants Before Treatment (Cubic Inches)	Size After Two Years Treatment (Cubic Inches)	Correction Due to Regression*	Corrected Final Size† (Cubic Inches)
Check (no fertilizer) . . .	52.94	511.68	+ 13.89	525.71
N ₁ PK	53.39	662.28	+ 10.63	672.91
N ₂ PK	53.83	628.73	+ 7.45	636.18
N ₁ PK	56.64	659.00	-12.87	646.13
N ₂ P	58.43	570.07	-25.81	544.16
N ₂ K	56.80	643.97	-14.03	629.94
N	55.67	580.65	-5.85	574.80
N ₂ PK (Urea)	54.48	676.36	+ 2.74	679.10
N ₂ PK (ammonium sul- fate)	53.74	663.77	+ 8.09	671.86
10 tons manure	52.65	676.10	+15.98	692.08
Average	54.86			

*Correction of final size for effect of size before treatments

†At odds of 99 to 1, a difference of 14.98 cu. in., or greater, becomes significant

phorus to Irish Juniper, at least when used with nitrate of soda. This is also substantiated by the fact that the N₂ PK treatment was not significantly better than N₂ K.

Sulphate of ammonia and urea gave better growth than nitrate of soda when used in equivalent amounts. Nitrate of soda used at the rate of 200 pounds, however, was as good as the other two nitrogen carriers. Cow manure, in the case of Irish Juniper, is shown to be somewhat better than any other treatment. The high quality of the manure used and the fact that 40 tons were applied per acre, over the 2-year period, would probably make this treatment too expensive to the nurseryman.

Some of the prejudice existing against the use of mineral fertilizers for evergreens no doubt arises from using too heavy applications. With deciduous trees, an excess application of sodium nitrate, for example, readily shows in foliage injury. With conifers, however, injury is more insidious in that severe stunting of the plants may occur without the familiar foliage evidence. On some supplementary plots in this study 800 and 1,200 pounds per acre, respectively, of sodium nitrate were applied twice yearly. The plants were very severely stunted but, without a basis of comparison, one might not have recognized the injury as being due to excessive nitrate. Arborvitae was more affected than Juniper by these heavy applications.

Although the data for the first year's growth measurements are not presented in this paper, they are similar but of less magnitude than the 2 years' results herein reported. Under our conditions and on the basis of 2 years' results, it is concluded that there is a differential response between the two species of plants used; that increased growth of arborvitae may be expected from applications of phosphorus and potassium as well as from nitrogen but that in the case of Irish Juniper only nitrogen and potassium are beneficial; that it makes little difference which of the several nitrogen carriers used in this work is applied,

provided it is in the proper amount; and that mineral fertilizers of the proper proportion can be advantageously substituted for manure. These fertilizer plots are to be continued for additional records.

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The Winter Hardiness of Some Woody Plants¹

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THE problem of the winter hardiness of wood plants in the latitude of West Virginia has always been a serious one, perhaps more so than in latitudes farther north. Winters in the lower altitudes (500 to 1,600 feet) are frequently characterized by rapid temperature fluctuations varying from zero or lower to 50 to 70 degrees F. At the higher altitudes (1,600 to 4,000 feet) temperatures often go as low as in New England with fluctuations as wide as at lower elevations, but the range is through a lower part of the temperature scale and consequently less injury results.

Great damage was done to flower buds and wood of many plants growing at the lower elevations during the severe winter of 1935-1936. On January 23rd, 1936, temperature at the Experiment Station Farm near Morgantown dropped from 50 to -16 degrees F in 12 hours, accompanied by a high wind. This resulted in severe injury to flower buds of certain species, as indicated in Table I, and by varying degrees of wood injury to both ornamental and fruit plants. Many dead twigs and branches were found in *Deutzia gracilis*, *Weigela rosea*, *Spiraea prunifolia*, *Spiraea thunbergii*, *Ligustrum amurense*, *Ligustrum ibolium*, and *Symphoricarpos racemosus*. *Ligustrum ovalifolium*, *Buxus* sp., and all varieties of climbing roses were killed to the snow line.

TABLE I—WINTER HARDINESS OF FLOWER BUDS OF CERTAIN HORTICULTURAL PLANTS AT MORGANTOWN, WEST VIRGINIA, 1935-1936 (MINIMUM TEMPERATURE -16 DEGREES F)

90 Per Cent or More Flower Buds Alive	90 Per Cent or More Flower Buds Dead
<i>Amelanchier canadensis</i>	<i>Cornus florida</i>
<i>Azalea (sp)</i>	<i>Deutzia gracilis</i>
<i>Berberis thunbergii</i>	<i>Forsythia (sp)</i>
<i>Cercis canadensis</i>	<i>Kerria japonica</i>
<i>Deutzia Lemoine</i>	<i>Prunus avium</i>
French hybrid lilacs	<i>Prunus cerasus</i>
<i>Philadelphus (sp)</i>	<i>Prunus domestica</i>
<i>Pyrus coronaria</i>	<i>Prunus instilitia</i>
<i>Pyrus malus</i>	<i>Prunus persica</i>
<i>Rhododendron catawbiense</i>	<i>Prunus serrulata (var. Kwanzan)</i>
<i>Rhododendron maximum</i>	<i>Rhododendron carolinianum</i>
<i>Ribes aureum</i>	<i>Rosa hugonis</i>
<i>Spiraea Anthony Waterer</i>	<i>Spiraea vanhoulei</i>
<i>Spiraea Billiardii</i>	<i>Weigela rosea</i>
<i>Syringa vulgaris</i>	

Damage to fruit trees was also severe, particularly peaches in which striking varietal differences were noted (Table II). It was observed that in a 2-year planting, South Haven showed less injury than Salberta. Many leaf-buds of plum and sweet cherry were injured, but damage in general was not great enough to affect materially the subsequent growth of the trees.

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TABLE II—DIFFERENCES IN WOOD INJURY TO PEACH VARIETIES (STATION ORCHARD, MORGANTOWN, 1935-1936)

Slight to Moderate	Moderate to Bad	Nearly Dead
Admiral Dewey	Brackett	Belle
Banner	Burton	Billmeyer
Berenice	Champion	Gibson
Buttercup	Early Elberta	Hiley
Carman	Elberta	Japan Dream
Chairs	Late Elberta	J. H. Hale
Early Mamie Ross	Massasoit	Krummel
Eclipse	Mayflower	Late Crawford
Engle	Pioneer	Meteor
Golden Jubilee	Ray	Nectar
Greensboro	Salwey	
Marigold	Shippers	
Kalamazoo	Slappy	
Rochester	South Haven	
Smock		
Sunbeam		

Some damage also was evident on the apple at this temperature (-16 degrees F). The flower buds were uninjured but the conducting tissue immediately below the fruit buds was moderately to severely browned. Pith tissue seemed more hardy, followed in order by bark and cambium. Terminal and lateral buds and those on young spurs were injured less than those borne on old spurs. Where browning was moderate to severe, flowers were retarded in their development or failed to open. Where there was eventual recovery, conduction of water and possibly other nutrients must have occurred either through injured xylem or through uninjured bark tissue. The spur leaves in most cases opened, the rate depending on the severity of the injury. Although no live cambium could be observed in such buds under a wide field binocular (30X) some live cells must have remained. Failure of flowers to develop must have been caused by the complete cutting off of water (a) before sufficient new tissue could be laid down by the injured cambium, or (b) because cambial tissue was dead. Conducting and pith tissue below leaf buds showed little, if any, browning. Varieties suffering most were Delicious, Grimes and Golden Delicious. Rome, Oldenburg, and McIntosh suffered least.

In a group of red raspberries including the varieties Chief, Latham, Newburgh, Viking, and Potomac (purple) the greatest injury occurred upon Viking. This injury was not severe and consisted of the killing back of the terminals of new canes.

In the northern panhandle of the state temperatures dropped to -22 to -25 degrees F on the same night of January 23rd. Other weather conditions were similar to those previously described. Injury was correspondingly greater than at Morgantown. Peaches and sweet cherries were severely damaged, but there was less opportunity to observe varietal differences. In a 3-year-old planting, Elberta showed least injury, followed in order by South Haven and J. H. Hale. In another block Belle was injured more than Elberta. The same types of injury were found on the apple as at Morgantown with the addition of severe

trunk injury to many varieties. The Baldwin suffered most, 30 to 50 per cent being killed or badly damaged. In one orchard York and Jonathan were badly hurt.

In the mountain areas of the eastern panhandle temperatures went as low as in the northern panhandle. In general the injury was similar, although trunk injury to the apple was less and bud injury more severe. Varietal differences were similar to those at Morgantown. Very severe trunk damage occurred on peaches, the most pronounced being on J. H. Hale.

At the Reedsville branch station where the temperature went to -32 degrees F, the following black raspberry varieties were under test: Black Beauty, Cumberland, Logan, Naples, Plum Farmer, and Quillan. Black Beauty came through best, although none were severely hurt. Chief, Cuthbert, Latham, Newburgh, and Viking red raspberries were under test, with Latham and Newburgh showing least injury.

OTHER FACTORS AFFECTING THE WINTER INJURY

The rate of temperature fall may be more important than the absolute temperature that obtains. Since the temperature dropped on a sunny day from above freezing to -16 to -32 degrees F, it was doubtless an important factor causing the severe damage. The high wind accompanying the drop hastened the rate of fall.

The effect of the preceding crop was also concerned in the severe apple trunk injury in the northern panhandle. Severely damaged Baldwin trees, for example, bore heavily last year. Even Wealthy trees that had heavy crops last year were badly injured. This was not a factor with peaches since there was little or no crop in the state in 1935.

Wood maturity seems to have been important. A small block of Elberta in sod at Morgantown showed much less injury than an adjoining block under cultivation. In a large apple orchard in the northern panhandle the greatest injury occurred in "draws" sheltered from the wind. Here growth may have continued later due to more optimum moisture conditions.

The general vigor of the tree affected injury. With peaches, the older the tree the greater was the damage. Young blocks 2 to 4 years old have shown no trunk killing and have made excellent recovery, while older trees were badly injured or killed outright. This is difficult to explain on the basis of lack of maturity. Trees severely infested with borers were damaged greatly. Vigor was probably a factor here. In a block of Elberta and Shippers at Morgantown with a row of each fertilized with nitrogen at different times, *viz.*, April, June, July, and October, no differences in injury were evident. One row was girdled (scored) in June with an idea that it might increase fruit bud hardiness. A slight yellowing of foliage and cessation of growth followed the treatment. Almost every tree in this row was killed outright by the low winter temperature.

The relative hardiness of different tissues has been carefully determined by other investigators (1). These studies show pith to be most tender. Evidence from this last winter, however, indicates that with

the apple the xylem tissue below the fruit bud is more tender than the pith.

Many apple trees completely girdled still showed no ill effects by mid-July. Others showed yellow foliage or were nearly dead, particularly where injury extended upon the main scaffolds for some distance. Amount of dessication of xylem tissue in trunk and limbs as well as the quantity of food reserves present in the plant may explain these differences in behavior.

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Fertilizer Trials With Shade Trees in the Nursery

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EXPERIMENTS dealing with applications of fertilizer to shade trees in the nursery have been under way since the fall of 1931. The methods and procedure followed and the data recorded during the first 3 years were presented at the meeting of this Society in 1934 (1). The data presented here has accumulated during 1935 and 1936. As stated in the previous report, 25 trees were included in each plot and applications of fertilizers were computed on the basis of adding $\frac{1}{4}$ pound of nitrogen and $\frac{1}{2}$ pound of superphosphate (Plots 5, 10, 15, 20) per inch in diameter of the tree. The average caliper of all trees at the end of the season is used as a basis for all fertilizer allocations the following season. The fertilizer is spread broadcast over the entire area beneath the spread of the branches. Measurements were taken with a standard caliper at a permanent mark on each tree approximately 2 feet above the bud union.

Table I presents data for each plot during 1935 and 1936. Tables II and III present composite data recorded during the years of 1933, 1934, 1935 and 1936, for all fertilizers applied at the different periods and for each fertilizer applied at all periods. Even though these experiments have been in progress for 5 years, this paper should be considered as a progress report. The inconsistency of the data recorded is indicative of the fact that fertilizer experiments on woody ornamentals out of doors must be of a long time nature.

As previously reported, an adequate rainfall is necessary for a favorable reaction from fertilizer applications. As a general summation it may be stated that a fair to ample rainfall occurred during the falls of 1932, 1933 and 1935. It was low during 1934. Rainfall was fair to ample during the summer of 1933 and 1935, low during 1934 and 1936. Fair to ample rainfall occurred during the early spring of 1935 and 1936 but was low during 1933 and 1934. These differences in rainfall together with the variation of topography of the land accounts for much of the inconsistent data. The general topography would indicate that plots 4, 5, 6, and 7, and 10, 11 and 12 were the most favorably located as to moisture retention. Plots 1, 2, 3 and 8 being less favorable, followed by plots 16, 17 and 18, then plots 9, 13, 14, 15 and 19 and final plot 20, the least favorable of all.

A review of Table II will show that the difference between the periods of application have not been great but the relationships have been fairly consistent throughout the course of the experiment. This is especially true for the composite data for the years 1933-34, 1933-35 and 1933-36. Based on the average increase in trunk diameter and including all fertilizers, the fall application has been better than the spring application and the combined fall and July applications have exceeded the combined spring and July applications. An analysis of all the data for each kind of fertilizer shows that with the 12-6-4 fertilizer, spring applications have been the best while the fall applications were the poorest both years. With 6-6-4 the combined spring and summer applications were best both years. The fall application was

TABLE I—THE RESPONSE OF MOLINI. ELMS (*Ulmus americana moline*) TO FERTILIZER TREATMENTS

Plot	Fertilizer Applied	Amount Applied (Pounds)	Time of Application	Average Diameter of Trunk per Plot (Cms)	Average Increase of Caliper per Plot (Cms)
1935					
1	Control	2.5	Oct. 8	4.20	1.66
2	12-6-4	5.0	Oct. 8	4.61	1.81
3	6-6-4	1.5	Oct. 8	4.69	1.86
4	Ammonium sulphate 20 per cent Superphosphate 20 per cent	3.75	Oct. 8	5.16	2.04
5	Ammonium sulphate 20 per cent Superphosphate 20 per cent	3.75	Oct. 8	6.02	2.08
7	12-6-4	2.5	July 10 and Oct. 8	5.30	2.10
8	6-6-4	5.0	July 10 and Oct. 8	4.90	1.96
9	Ammonium sulphate 20 per cent Superphosphate 20 per cent	3.75	July 10 and Oct. 8	4.47	1.71
10	Ammonium sulphate 20 per cent Superphosphate 20 per cent	3.75	July 10 and Oct. 8	5.50	2.32
11	Control	2.5	June 1	5.15	2.09
12	12-6-4	5.0	June 1	5.82	2.48
13	6-6-4	1.5	June 1	4.76	1.99
14	Ammonium sulphate 20 per cent Superphosphate 20 per cent	3.75	June 1	3.74	1.32
15	Ammonium sulphate 20 per cent Superphosphate 20 per cent	3.75	June 1	4.76	1.96
17	12-6-4	2.5	June 1 and July 10	5.24	1.91
18	6-6-4	5.0	June 1 and July 10	5.57	2.18
19	Ammonium sulphate 20 per cent Superphosphate 20 per cent	3.75	June 1 and July 10	4.46	1.63
20	Ammonium sulphate 20 per cent Superphosphate 20 per cent	3.75	June 1 and July 10	3.96	1.42

TABLE 1—Continued

Plot	Fertilizer Applied	Amount Applied (Pounds)	Time of Application	Average Diameter of Trunk per Plot (Cms)	Average Increase of Caliper per Plot (Cms)
1936					
1	Control	—	—	5.12	0.92
2	12-6-4	4.0	Oct. 9	5.93	1.37
3	6-6-4	8.0	Oct. 9	6.01	1.23
4	Ammonium sulphate 20 per cent	2.5	Oct. 9	6.52	1.36
5	{ Ammonium sulphate 20 per cent Superphosphate 20 per cent }	{ 2.5 5.0 }	Oct. 9	7.66	1.61
7	12-6-4	4.0	July 24 and Oct. 9	6.98	1.44
8	6-6-4	8.0	July 24 and Oct. 9	6.36	1.31
9	Ammonium sulphate 20 per cent	2.5	July 24 and Oct. 9	5.85	1.23
10	{ Ammonium sulphate 20 per cent Superphosphate 20 per cent }	{ 2.5 5.0 }	July 24 and Oct. 9	7.16	1.65
11	Control	—	—	6.93	1.72
12	12-6-4	4.0	April 3	7.78	1.73
13	6-6-4	8.0	April 3	6.03	1.23
14	Ammonium sulphate 20 per cent	2.5	April 3	5.18	1.21
15	{ Ammonium sulphate 20 per cent Superphosphate 20 per cent }	{ 2.5 5.0 }	April 3	6.22	1.34
17	12-6-4	4.0	April 3 and July 24	7.14	1.47
18	6-6-4	8.0	April 3 and July 24	7.20	1.55
19	Ammonium sulphate 20 per cent	2.5	April 3 and July 24	6.08	1.35
20	{ Ammonium sulphate 20 per cent Superphosphate 20 per cent }	{ 2.5 5.0 }	April 3 and July 24	5.35	1.29

TABLE II—AVERAGE INCREASE IN TRUNK DIAMETER PER SECTION

Section	Plots	1933 (Cms)	1934 (Cms)	1935 (Cms)	1936 (Cms)	Average Increase in Trunk Diameter		
						1933-34 (Cms)	1933-35 (Cms)	1933-36 (Cms)
Fertilizer applied in fall	2-3-4-5	.68	.83	1.92	1.39	.76	1.14	1.21
Fertilizer applied in fall and July	7-8-9-10	.69	.62	2.02	1.41	.66	1.11	1.19
Fertilizer applied in spring	12-13-14-15	.63	.47	1.94	1.38	.55	1.01	1.11
Fertilizer applied in spring and July	17-18-19-20	.75	.57	1.79	1.42	.66	1.04	1.13
Controls	1-11	.49	.69	1.88	1.32	.59	1.02	1.10

TABLE III—AVERAGE INCREASE IN TRUNK DIAMETER PER TYPE OF FERTILIZER APPLIED

Section	Plots	1933 (Cms)	1934 (Cms)	1935 (Cms)	1936 (Cms)	Average Increase in Trunk Diameter		
						1933-34 (Cms)	1933-35 (Cms)	1933-36 (Cms)
12-6-4	2-7-12-17	.66	.77	2.08	1.51	.72	1.17	1.26
6-6-4	3-8-13-18	.72	.57	2.00	1.33	.65	1.10	1.16
Ammonium sulphate 20 per cent	4-9-14-19	.59	.49	1.68	1.29	.54	.92	1.01
Ammonium sulphate 20 per cent	5-10-15-20	.77	.65	1.95	1.47	.71	1.12	1.21
Superphosphate 20 per cent		.49	.69	1.88	1.32	.59	1.02	1.10
Controls	1-11							

the poorest in 1935 and the spring application in 1936. With ammonium sulphate the relationship between the different types has been the same each year, the fall applications were best and spring applications the poorest. With the fertilization of ammonium sulphate and superphosphate the combined fall and summer applications have been best and the spring and summer applications the poorest. It will be noticed that these data check rather closely with the suggested relationship of the plots to favorable moisture supply.

The data recorded in Table III show that applications of a complete fertilizer high in nitrogen and ammonium sulphate plus superphosphate were most beneficial. The increase shown by these two types of fertilizer over others is consistent over the past 4 years. Applications of ammonium sulphate have given the poorest results each year.

The control plots have varied considerably but an average of them shows a rather high increase in trunk diameter, in fact they have exceeded the average of the plots to which ammonium sulphate has been applied. This can be accounted for by the favorable location of control plot 11. The reaction of the trees in this plot would seem to indicate that a favorable moisture supply was more important to the growth of young trees in a good soil than additional applications of fertilizers.

Since the same quantity of nitrogen was applied with both the 12-6-4 and the 6-6-4 fertilizers one would not expect much difference to appear between them if nitrogen is the element mainly responsible for growth. The tests have not been conducted over a long enough period to warrant definite statements, but the results so far, and as presented in Table III, might lead to the fact that while phosphorus aids in growth, as shown by the poor results where it was omitted, apparently only small quantities are required on this particular soil type to bring about the stimulation. The basis for this statement lies in the fact that the 12-6-4 fertilizer gave the best results although the 6-6-4 and combined ammonium sulphate and superphosphate contained two and five times as much phosphorus respectively. Since the 6-6-4 fertilizer as applied added twice as much potash as the 12-6-4 and the fact that no potash was added with the ammonium sulphate-superphosphate mixture, there seems to be little advantage, at present, from the addition of the potash elements to the soil in this experiment.

The tentative conclusions which may be drawn from this 5-year test are: (a) Ample moisture is necessary for a favorable response of small trees to fertilizer applications; (b) in general, fall applications appear more beneficial than those made in the spring; (c) a complete fertilizer high in nitrogen or a mixture of ammonium sulphate and superphosphate are best of the sources tested; (d) applications of ammonium sulphate alone have given little stimulation; (e) potash does not seem necessary in this particular soil type to date, and (f) ample moisture seems more important for stimulating growth of young trees in good soil than additional applications of fertilizers.

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A Retrospect

Looking Back Ten Years on Floricultural Research

By ALEX LAURIE, *Ohio State University, Columbus, Ohio.*

SINCE our hindsight is always better than our foresight, it is easier to review past accomplishments than to predict future developments. So it is my purpose today to bring before you a panoramic view of the accomplishments of the junior branch of horticultural science during the past decade. It must be conceded at the start that research in floriculture has lagged behind the other branches and there are rather valid reasons for this state of affairs. With your permission I should like to analyze this condition.

Floricultural instruction is of relatively recent origin and hence the workers in the field are comparatively few. The original departments of horticulture stressed the more necessary economic branches of pomology and vegetable gardening and but scant attention was paid to floriculture, presumably a foundling to be tolerated but not encouraged. This lack of encouragement can be traced partially at least, to the heads of departments who were trained in pomology or vegetable gardening and with overwhelming problems in their own fields staring them in the face, failed to realize the needs in other directions.

Growing out of this condition, need for special equipment for floricultural work was neither realized nor sought. Furthermore, the profession of gardeners based on empirical practices handed down from generation to generation and with closely guarded secrets, made no demands on the professional horticulturists. This lack of demand for the solving of pressing problems, together with lack of leaders in the floricultural field, resulted for many years in virtual stagnation and I might state in passing that considerable prejudice still exists in the minds of the commercial growers and gardeners and skepticism reaches its heights when "the professors" are accused of being responsible for the many new pests of the plant world, because apparently the difficulties experienced with these have been coincidental with the advent of these self-same "professors" into the field of floriculture.

Fortunately for floricultural teaching and research, and perhaps by the grace of God, at least three men with inclinations toward ornamentals were placed at the head of their respective departments at Massachusetts, Cornell, and Illinois. They were Professors Waugh, Bailey and Blair. Gradually these institutions began to evolve into specialized departments of floriculture and laid the foundations for the present group of teachers in that field. These three institutions were presently joined by others and the swing toward floriculture assumed measurable proportions.

The teaching and research in the earlier days was based on the practices gleaned from the less secretive of the commercial men who either revealed their secrets in print or by admission of "rank outsiders" to their establishments. The research was based almost entirely on classification of varieties and the attempts to clarify nomenclature.

As I look back upon those days I am amazed at the meager information imparted to the students. In fact, my first job as a propagator with a large nursery, which I secured largely because of fraternal association with the son of the owner of that firm, necessitated my spending several weeks incognito in a large nursery center in order to learn the most common and simple methods.

Gradually those of us who graduated from the original institutions with departments devoted to floriculture, began to break down the existing prejudices both on the parts of our colleagues and the industry. Slowly but surely the instruction improved and began to be based on the fundamental sciences and with that came the initial sporadic attempts to solve the many pressing problems in the field. This briefly, brings us to the point of this retrospect—the turn of events during the last 10 years, which in some instances has resulted in the tail wagging the dog.

As indicated previously, the initial efforts at research in floriculture consisted largely of the classification of varieties and Cornell took the lead in this field for many years, simplifying nomenclature and reducing the many duplicates to a common denominator. Such crops as roses, peonies, gladiolus, iris, sweet peas and others came in for their share of attention and contributions of value were made.

This was concurrent with studies in soils and fertilizers in the attempt by means of comparative plots to correlate and clarify the existing empirical practices and to apply where possible, the findings of the workers in soil science. The artificial conditions of heat, moisture, aeration and light, together with intensive culture, set greenhouse culture in a class by itself and many modifications of field culture were essential before diagnosis of results and satisfactory recommendations could be depended on.

The work at Illinois, Michigan, Ohio and Cornell has been particularly noteworthy. They used plot technique primarily to determine the plant needs in three elements found most deficient in soils—nitrogen, phosphorus, and potassium. Studies with most of the major greenhouse crops and some of the garden materials have resulted in the present recommendations which are more or less followed by the commercial growers. As a further and most recent outgrowth of these tests, the matter of chlorosis of roses, hydrangeas, azaleas, and oaks has received considerable attention, particularly at Ohio and New Jersey. The recommendations for the use of ferric and ferrous sulphate as antidotes are now fairly standard practices. The coloring of the hydrangea flowers through the use of aluminum was clarified by workers at Cornell, New Jersey and Ohio. It is interesting to note in this connection that the theory still held by some workers that iron is the limiting element in color of hydrangeas, has been disproven, for with dilute solutions of aluminum citrate sprayed on the developing bracts it is possible to produce desired change from pinks to blues.

As a further outgrowth of the work with nutrients, New Jersey, Ohio and Purdue have been intrigued by sand culture of crops. The present status of this research is of sufficiently clear nature to warrant the use of sand or mixtures of sand and peat in commercial prac-

tice, the application of nutrients being made in water soluble form directly to the top of the sand or by means of sub-irrigation, the latter method making the additions practically automatic, even to the extent of making definite allowances for light deficiencies during winter months. A variation of this system developed at Ohio, is the use of quickly soluble dry materials, which lends itself quite satisfactorily to the commercial practice. As a result of these tests, New Jersey found that in the case of carnations, freedom from disease, reduction in calyx splitting and economy in operation results. Further, it was determined that sleepiness in carnations may be due to too much heat, too much available nitrogen, and too high a humidity, whereas excess of phosphorus may result in the adhesion of petals. Likewise, the same workers found that bud drop in sweet peas during the winter was the result of very succulent immature type of tissue and rapid abscissing of flowering buds. Grown in sand with high concentration of nitrogen in a nutrient solution of 2 to 3 atmospheres, bud drop was reduced to a minimum.

As a further development of nutritional studies, the Ohio Station has worked out a series of symptoms of nutrient deficiencies on the majority of greenhouse crops, so that it is quite possible to ascertain visually these deficiencies. This work was done under sand culture with constant drip and was verified by detailed microchemical tissue tests. Soils lacking in various essential elements were likewise used and the occurring deficiencies quickly and effectively corrected by supplying the needed elements to the soil.

Soil reaction studies have determined fairly conclusively the ranges of pH most suitable for the majority of greenhouse and some outdoor ornamental crops. The Ohio, New Jersey and Illinois Stations were largely responsible for this work.

Soil sterilization with steam has come in for its share of attention at Illinois and Ohio, as a result of which much improvement has been seen in commercial practices.

Cornell and Ohio have been responsible for what little work has been done with fertilizers on trees, while Michigan and Ohio and Minnesota have studied peats to a considerable degree.

Probably the most outstanding contribution in the field of floriculture has been made in photoperiodism and its practical application to commercial crops. Following the initial researches by Garner and Allard, the Ohio Station, followed by Cornell and later Purdue, studied the short and long day plants and the effect of reducing the daylight period artificially as well as the effect of supplementary illumination by means of electric light.

The reduction of daylight period has necessitated the practical studies to determine the materials most satisfactory for the exclusion of light (over 1 per cent admitted light is not satisfactory), the length of day needed, the period in the life of the plant when the reduction should take place, its total length, the studies of species and varieties most suitable, and the attempt to determine the cause of the reaction. The last problem is being studied in detail at the Ohio Station both from the anatomical and chemical standpoints. The commercial plants which respond to day length reduction are chrysanthemum, *Stevia*,

Bouvardia, Begonia, Kalanchoe, Euphorbia, and a number of others.

The research with supplementary illumination has been done largely by Boyce-Thompson Institute, Ohio, Purdue and Cornell, with some sporadic attempts at other institutions. Studies in intensity of illumination, the quality of light, the duration of additional illumination, the period in the life of the plant when this illumination is most beneficial, the species and varieties of flowering plants which respond to this treatment, and the causal effects have constituted the major projects. Studies at Purdue in particular have indicated the following:

The threshold intensity for photoperiodic responses to white light varies greatly with different plants. For stock, Lilac Lavendar, the threshold ranges from 5 to 10 foot candles; pansy, Giant Swiss Blue, 5 to 10 foot candles, and aster, Heart of France, 0.3 to 1 foot candles. The flowering condition is stimulated in these three plants by long days produced artificially with low intensity Mazda lamp radiation. The aster is the most sensitive plant with which they have worked, and will show certain flowering responses with intensities well below 0.3 foot candles.

The flowering condition is induced in long day plants and the vegetative condition induced in short day plants by low intensity orange-red radiation of wavelengths between 650 to 720 millimu. During the shorter winter days at relatively low temperatures, 50 to 55 degrees F, such plants as aster, scabiosa and sunflower become reproductive in the presence of low intensity red light at night. Short day plants, such as salvia, cosmos and Tithonia, remain in vegetative state as a result of the red radiation. The other regions of the spectrum have relatively little effect upon these plants. Temperature has a marked influence upon these responses, and in the case of aster, the reproductive condition manifests itself in either long or short days of temperature at 65 to 70 degrees F.

The study of high intensity gaseous tube lamps as sources of radiation for the growing of plants under conditions of either low intensity or solar radiation has been made. It has been found in a series of basement dark rooms that under conditions of equal power consumption per square foot of bench space the sodium lamp is the most effective in synthesizing the carbohydrates in the seedlings used. The high intensity mercury arc and neon lamps are relatively less effective than either sodium or Mazda lamps on an equal power basis. The sodium lamp, however, induces the most spindling weak type of growth, with the Mazda lamp second, and the mercury arc induces a type of growth very similar to that under normal conditions except for its relatively slow rate. The seedlings used were sunflower, tomato, buckwheat and Tithonia.

Optimum temperatures as well as possibilities in breaking dormancy in the bud stage by means of temperature variants have been and are being studied rather intensively. Cornell is attempting to determine the optimum temperatures, as well as ranges of temperature in flower bud initiation with greenhouse plants. The United States Department of Agriculture has led the way in precooling bulbs for early flowering, while studies in precooling stocks have been made at Ohio, Cornell

and Illinois. Preheating corms of gladiolus, together with special forcing technique have resulted in interesting developments through the work done at California, Iowa, Illinois and Ohio. Preplanting temperatures of 85 to 100 degrees F have produced gladiolus flowers several weeks in advance of the normal flowering time.

Breaking the rest period of hydrangeas with cold temperatures has produced early flowering at Cornell, while Massachusetts has shown that clumps of delphiniums stored in temperatures of 34 to 36 late in the summer for a period of 8 weeks, flowered in November and December.

Moisture studies at Ohio have shown that the maintenance of uniform moisture in the soil at all times is most satisfactory; that heavy watering (1 gallon to 2 square feet of soil, 6 inches deep) is more satisfactory than light watering; that late afternoon watering is better than morning or noon; that humidity regulation in the atmosphere is responsible for length of stems of lilies and is necessary for the control of bud drop in gardenias.

Undoubtedly the lions' share of the research done with vegetative means of reproduction and seeds has been done at Boyce-Thompson Institute. Their studies in after-ripening of numerous species of seeds, their germination requirements and metabolic reactions have given us a great insight into this phase of plant life. The use of various gases for the purpose of breaking the rest period of plants has likewise been a notable part of their work. In the propagation by vegetative means a great variety of work has been attempted and carried to conclusion by Boyce-Thompson Institute, Cornell, Ohio, Michigan, Illinois, Massachusetts, and Iowa, together with occasional contributions from other sources. The use of various media, such as sand, peat, cinders, slag, coconut fibre and various mixtures of these, has constituted a series of studies at these institutions. The moisture content, oxygen, as well as the hydrogen-ion concentration, has been given considerable attention. The application of various chemicals for root stimulative purposes has resulted satisfactorily in specific cases. Bottom heat at 5 to 10 degrees higher than the surrounding temperature has proven adequate in many instances. The position of cut, the studies of the suberin layer, the tissues responsible for the origin of roots, defoliation of cuttings, the humidity and moisture requirements, as well as the regions where the intake of moisture takes place, have been given due consideration. Studies have been made on the congeniality of stocks and cions together with attempts to determine the viability of stocks and cions by means of the starch tests. The most recent contributions in propagation deal with the growth promoting substances such as indolebutyric, indoleacetic, phenoleacetic, etc. and their relation to the rooting of cuttings. Preliminary studies, largely at Boyce-Thompson Institute, indicate possibilities in the stimulation of rooting of many *hardwooded* plants. This development is intriguing and because it borders on the spectacular, lends itself greatly to considerable exploitation and advertisement.

Some study has been devoted to the growing of outdoor planting under aster cloth. Started as a means of exclusion of leaf hoppers, car-

riers of aster yellows, by Jones of Wisconsin, the work was carried on further by Cornell and Ohio to include the growth of many plants such as roses, chrysanthemums, sweet peas, marigolds, and others for commercial production. Due to the 35 to 40 per cent reduction of total light, the greater humidity under cloth as well as more uniform moisture in the soil, together with reduction of transpiration, the quality of the flowers so grown is greatly enhanced. Richer coloring, longer stems, larger foliage, all result from such a treatment. In localities where extreme heat persists during the summer months, certain crops may be carried over under cloth, whereas without it they perish. The Boston yellow daisy is a typical example. Likewise, in such localities, hydrangeas, gardenias and azaleas are benefited by planting under cloth.

Scientific plant breeding has been limited in its extent. California and Massachusetts have done some work with developing rust proof snapdragons and wilt proof asters. Both have been largely successful. Breeding with chrysanthemums, carnations, and roses has been carried on by Illinois and Iowa while other institutions have made sporadic attempts in the same direction. At present the workers in Floriculture at the United States Department of Agriculture under the direction of Dr. Emsweller, are devoting much effort to the breeding problems with ornamentals.

Although many attempts have been made to study the keeping qualities of cut flowers, little definite and specific information is yet available. The workers at Illinois, Iowa, Cornell, Boyce-Thompson and Ohio are largely responsible for these studies. The use of various chemicals as well as carbon dioxide has been tried with some degree of success in specific cases. Cutting of stems under water to eliminate air from water conducting vessels, has proven of value, copper has been found valuable largely as a disinfecting agent. At present, studies in Ohio are being made with correlations between refrigeration and humidity as well as the factors which reduce respiration rate and rapid maturity. The following materials have shown promise: hydrozene sulphate, fluoreglucinol and resinol. Sodium amycol was effective on sweet peas presumably because of its coagulative action of proteins.

Physiological, morphological and anatomical studies in floriculture in the various institutions have not reached the high stage of development attained by other Horticultural groups. New Jersey, Boyce-Thompson Institute, Cornell, Iowa and Ohio have contributed to our knowledge of nitrogen metabolism, morphology of gladiolus, anatomy of roses and chrysanthemums, and a number of other minor investigations.

The economics of the industry have received but scant attention. Nothing to speak of has been done except for the compilation of data on costs of production by Ohio and Michigan and the present studies at Ohio of consumer interest in flowers.

This survey of the present status of research in floriculture obviously does not attempt to catalog the many minor projects undertaken by the various institutions. Any omission of major interest which may have occurred has not been committed intentionally and may be due

partially to the lack of response on the part of workers to whom a letter of inquiry was addressed several months ago.

The survey shows that progress is being made slowly and in some instances, painfully, but nevertheless progress it is. The needs of the future call for greater concentration on the fundamentals without losing sight of the many pressing problems of practical nature. As an example may be cited the dire need of information relative to the bud drop of gardenias. It is definitely a problem for the physiologist with the multiple factors of light, humidity, temperature, and nutrition playing their complex roles. Yet while this is being attempted, any leads of promising nature should be divulged to the anxiously waiting commercial grower and the other workers in the field. Another example which illustrates the point even more clearly is the case of day length reduction on the chrysanthemum or the supplementary illumination of long day crops. Whereas it is necessary for us to know the underlying factors concerned in the effect produced, that may take many years, hence why keep a good thing to ourselves when we already know how to do it, even if we are in the dark as to the reasons for its occurrence. It may look like a backward procedure to the scientist to develop a method and then go back and find out how it came about, but after all, at least part of our duties in serving our states and constituents is to solve problems as quickly as possible.

This brings us to another controversial point, particularly among the juveniles in floriculture. As a result of the demand for research and the solving of problems quickly, some are led to the dissemination of results and the drawing of conclusions which are based on inadequate data or lack of sufficient replication. Such a method is permissible provided that the results are broadcast as progress reports with precautions against general and indiscriminate application. Again such a means is permissible provided that the worker is not prejudiced and biased either by half-baked theories or by an inordinate desire to discredit the other fellow.

It is quite possible, as you all know, to secure contradictory results at two different places because of failure to take cognizance of the condition of plants before being placed under treatment and likewise because all limiting factors were not given due consideration. A common example of such a condition may be cited in the controversy as to which deficiency shows up first—that of phosphorus or that of potassium. If the fact is not recognized that an accumulation of one or the other may have developed before treatment, the results naturally would vary. As a consequence, controversial matters of this sort might better be discussed privately before undue publicity is given. Progress reports serve a very definite purpose and it seems to me that the withholding of publication for many years, presumably because of extreme care in checking or possibly because of timidity or procrastination, is not to be encouraged.

Contrary to the work done by the pomology and the vegetable groups, the workers in floriculture have considered a certain project their particular pet, to be guarded jealously and zealously, whereas actually, the greater the spread of the projects over a wide area, the

quicker the final solution is reached and the simpler it is to apply to the varying conditions of climate found in the country. The development of similar projects in various institutions is to be encouraged and the compiled data may well be studied and judged by groups to eliminate faults and erroneous conclusions. Group meetings of various institutions in each section of the country should be looked forward to as clearing houses of information, so that in the end our progress will not only be speedy but harmonious as well. After all, competitive as research may seem to have become, most of us are still inherently honest enough to give credit where credit is due and each individual and his identity and association with a certain discovery need not be lost, despite the cooperative effort suggested.

There is no question that the great variety of materials included in the field of floriculture lends itself to numerous problems. One of these may well take cognizance of the approach to breeding plants from the standpoint of chromosome relationship as indicated by the workers in England, particularly at John Innes Horticultural Institution. Other problems are of fundamental nature based on chemistry, physiology, anatomy, and other basic sciences. To cope with these problems successfully, the younger men, particularly in floriculture, because it has lagged behind in this respect, should make every effort to secure the needed training in these sciences. With such a preparation they should be able to keep abreast of the times and raise the level of floricultural research to that of other horticultural groups, and there is no question of this level being high, when we consider that the lowly horticulturists have been responsible for most of the outstanding work done in recent years in the field of plant physiology.

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